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Faculty of Agriculture & Life Sciences

Department of Pest-management & Conservation

Conservation biology project reports of Cleardale Station and Taniwha Farm, Rakaia Gorge, Canterbury, New Zealand

Edited by

Nick Dickinson & Mike Bowie

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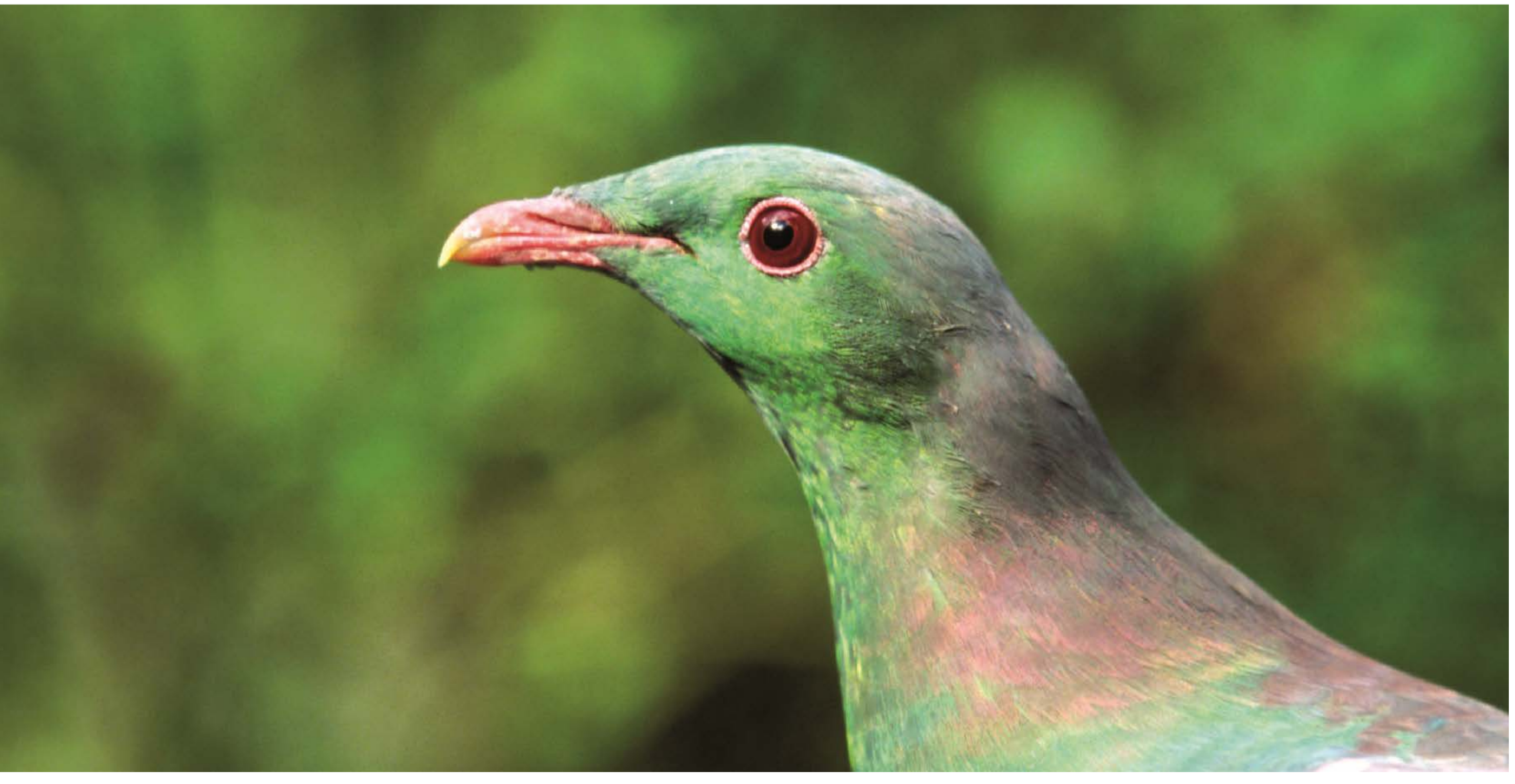

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Cleardale Station looking towards Rakaia River (Photo: Tanmayi Pagadala)

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Introduction

In each of the previous four years, ECOL609 (Conservation Biology) has been focussed on the South Island High Country, with a residential field course at Lincoln University's Mt. Grand Station at Hawea. Students have spent the first 3-4 weeks of this paper beginning to understand the ecology, farming systems and the many associated complexities of the South Island High Country, whilst also planning a research project at Mt Grand within their own particular area of specialism.

The day before our planned departure in March 2020, all residential field courses were cancelled in response to the global Covid-19 pandemic. Mike Bowie was enthusiastic to explore switching the field work to a series of day trips, to a location more easily accessible from Lincoln. At exceptionally short notice, Ben Todhunter and Donna Field agreed to allow us access to Cleardale Station and Taniwha Farm at Rakaia. Furthermore, Ben and Donna were exceptionally welcoming, kindly making themselves available to introduce us to their landholdings, the farms and this beautiful landscape. The two days were spent meeting Donna and Ben at their home and on site, exploring the farms, rapidly re-designing research projects into different topics, planning and setting up experiments and collecting data. We were also fortunate to coincidentally meet Di Lucas on site; later she kindly provided us with copies of her detailed descriptive mapping of landforms across Cleardale Station. We had just two days of intensive site visits before NZ entered lockdown, meaning distance learning was the only remaining study option. A brief pub stop at Hororata on the second day was the last opportunity for face-to-face contact for the group. The remainder of the semester was restricted to Zoom sessions, email and occasional one-on-one meetings. Despite the many constraints, including the lost opportunity of laboratory analysis of samples, all of the students successfully completed the course and a suitable amount of learning was achieved. Equally importantly, this was an experience enjoyed by students and tutors alike. We hope there will be a future opportunity to return to Cleardale and Taniwha with student groups in the future. Meanwhile we extend our sincere thanks to Ben and Donna.

This document provides a small reflection of a significant educational achievement, though this collection of summary research reports provided by the students. Editing has been limited to copy-editing and removal of some parts of the introductory sections that seemed repetitive for a collated report of this type. We are grateful to Fiona Bellinger for skilfully collating and organising this report.

Nick Dickinson & Mike Bowie [Eds.]

Cleardale and Taniwha Stations

Cleardale Station and Taniwha Farm are situated in Canterbury on the true right bank of the Rakaia River approximately five kilometres upstream of the Rakaia Gorge. The stations range from 300 to 700 metres above sea level, with an area between them of 1600 hectares and annual rainfall of 1000 mm (B. Todhunter, pers. comm., March 17, 2020). The river flats and foothills of the Southern Alps encompassed by the two stations support a variety of habitat types including short-tussock grassland, native shrubland, stands of exotic trees, wetlands and remnant native bush. This variety of habitats is typical of a station in the foothills of the Southern Alps in the Canterbury region and is consistent with other stations in the area (Land Information New Zealand, 2005).

Taniwha is the smaller of the two stations and much of its area is not currently being farmed. This non-farmland includes a public walking track which follows the true right of the Rakaia River through an area of regenerating native bush, albeit with several invasive plant species. Cleardale is the larger station and of greater potential conservation value, due to the wide range of habitat types it encompasses. In the higher altitude areas of the station there is short-tussock grassland, a vulnerable high country ecosystem with significant areas on private land such as Cleardale Station (Snoyink, 2015). Slightly lower on the slopes are small patches of remnant native bush with tree species such as broadleaf (*Griselinia littoralis*) and kowhai (*Sophora* sp.). Lower again are large stands of matagouri which give way to the Rakaia River and wetland areas.

Fraser Gurney

Chapter 1: **Habitat Preference of Birds**

Fraser Gurney

Abstract

New Zealand's birds have lost much of their habitat through clearance for agricultural land, particularly in the Canterbury region. With agriculture such a dominant part of the Canterbury landscape it is important to understand how to best enhance bird diversity in these farming systems. This study looks at habitat preferences of birds at Cleardale Station in the foothills of the Southern Alps near Rakaia where five-minute bird counts and acoustic recording devices were used in a range of habitats to measure bird diversity. 30 species of birds, 14 of which were native were recorded at Cleardale Station. Matagouri (*Discaria toumatou*) scrub had the highest bird diversity although there was limited time for data collection which could skew the results. To maximise bird diversity at Cleardale Station it is recommended that the farm be looked at as a whole rather than by individual habitat type. Creating more plantings and extending already existing trap networks by the Rakaia River to encompass remnant patches of native vegetation and planted areas is the most realistic option without interfering with the station's production.

Keywords: New Zealand, Canterbury, Cleardale Station, Five-minute bird count, Bird Recorder, Matagouri, Remnant Native Vegetation, Plantings

1.1 Introduction

Since human arrival in New Zealand the country's native avifauna has lost much of its habitat, in particular forest-dwelling birds which have lost 70% of their original habitat (Ewers et al., 2006). Much of this land clearance has been to make way for agriculture, in 2016 nearly half (45.3%) of New Zealand's total land area was being farmed (Ministry for the Environment, 2018). With agricultural land being so prevalent in New Zealand it is important to assess its ability to support the country's birdlife. This is particularly important in the Canterbury area which has the most agricultural land of any of New Zealand's regions (Ministry for the Environment, 2018).

The Rakaia is a braided river, a unique and distinct ecosystem with high conservation value due to the specialist species it supports (Department of Conservation, 2010). Nationally vulnerable wrybill (*Anarhynchus frontalis*) and nationally critical black-billed gulls (*Larus bulleri*) have breeding colonies in the Rakaia riverbed adjacent to Cleardale Station (B. Todhunter, personal communication, March 17, 2020).

The aim of the study is to find out which species of bird inhabit Cleardale Station and to determine which habitats support the greatest bird diversity. This encompasses identifying any bird species of conservation value and any areas or habitats with high bird diversity. Identification of such species and areas will enable station owners to make informed decisions about the best areas to protect and enhance to increase bird biodiversity on their land. The hypothesis for this study is that the areas of wetland habitat will have the greatest bird diversity and the greatest potential conservation value.

1.2 Methodology

This study was conducted on Cleardale Station rather than Taniwha Station, due to Cleardale's larger size, more diverse habitat types and greater potential conservation value. Bird numbers were measured through five-minute bird counts (5MBC) and the deployment of DOC AR4 V1.4 acoustic recording devices (bird recorders), both of which are standardised techniques for bird monitoring used by the Department of Conservation (Department of Conservation, 2020). Birds seen incidentally around the station were also recorded. Six sites were selected on Cleardale Station at which to record bird species, encompassing five different habitat types. Site 1 was short tussock grassland with scattered shrubs, Sites 2 and 3 was remnant native bush, Site 4 was matagouri scrub, Site 5 was a paddock pond and Site 6 was a wetland. Sites 1 to 4 all had a 5MBC conducted and a bird recorder deployed, Sites 5 and 6 only had a 5MBC due to time constraints. The locations of Sites 1 to 4 and shown in Figure 1 and Sites 5 and 6 in Figure 2. Bird counts were conducted on the 19/03/2020 and 20/03/2020 while the bird recorders were deployed on the 19/03/2020 and collected on 20/03/2020.

Figure 1-1: Aerial photograph of part of Cleardale Station with Sites 1 – 4.
A) Site 1, short tussock grassland. B) Site 2, remnant native bush. C) Site 3, remnant native bush. D) Site 4, matagouri scrub.

Figure 1-2: Aerial photograph of part of Cleardale Station with Sites 5 and 6.
E) Site 5, paddock pond. F) Site 6, wetland system.

The data from the bird recorders was analysed in the program kaleidoscope-5.1.9i, which allowed for both aural and visual inspection of the recordings using the program's spectrogram. To increase the likelihood of detecting species that were not detected during the 5MBC two hours of recordings at dawn (6am to 8am on 20/03/2020) and dusk (7pm to 9pm on 19/03/2020) were listened to and examined using the spectrogram. These times were chosen as no 5MBC were conducted in these time periods and for the increased rate of bird vocalisations associated with the dawn and dusk chorus's (Barnett & Briskie, 2007). The dusk recording period also increased the detection of nocturnal species (Jain, Diwakar, Bahuleyan, Deb, & Balakrishnan, 2014). The rest of the recordings were visually skimmed to detect any other bird calls on the spectrogram. Bird calls that were unable to be identified both aurally and visually were sent away to experts for conclusive identification.

After combining the 5MBC and incidental sightings data with the bird recorder data the number of bird species at each site was recorded, as well as the number of native bird species at each site. The relative importance of each habitat type was determined by the number of bird species and native species identified in that habitat type. The number of bird species and native bird species for the station as a whole were also recorded. It is important to note that the relative importance for each habitat is taken from data collected over only a two day period (which is not long enough to account for factors such as seasonal change), so care must be taken when applying the results from these methods to other situations. The data collection for the study was limited to two days due to restrictions put in place to combat the 2019/2020 COVID-19 outbreak.

1.3 Results

Of the six sites measured Site 4 (matagouri) had the greatest bird diversity with 15 species, of which five were native. Of those 15 species only four were recorded during the 5MBC, the other 11 were all identified from the Site 4 bird recorder. Conversely Site 1 (short tussock grassland) had the lowest bird diversity with just five species of which three were native. Of the five species at Site 1 three were recorded during the 5MBC, one was recorded incidentally and one was identified from the Site 1 bird recorder. Sites 2 and 3 were both at native bush remnants and accordingly had very similar results. Site 2 had 10 bird species of which four were native, with four bird species being recorded during the 5MBC and six identified from the Site 2 bird recorder. Site 3 had nine bird species of which three were native, with six bird species being recorded in the 5MBC and three identified from the Site 3 bird recorder. Sites 6 (paddock pond) and 7 (wetland) both had seven bird species recorded during their respective 5MBCs of which five were native, neither side had a bird recorder present.

Table 1-1: A summary table showing the number of species and number of native species for each site and Cleardale Station as a whole.

Site	Number of Species	Number of Native Species
Site 1	5	3
Site 2	10	4
Site 3	9	3
Site 4	15	5
Site 5	7	5
Site 6	7	5
Cleardale Station Total	30	14

A total of 30 bird species were recorded at Cleardale Station of which 14 were native (Table 2). One of these species (grey duck X mallard hybrid) is a hybrid taxa and not a full species but in this study is referred to as a species for consistency. Four of the 30 detected bird species – black shag (*Phalacrocorax carbo*), sacred kingfisher (*Todiramphus sanctus)*, Eurasian skylark (*Alauda arvensis*) and New Zealand Pipit (*Anthus novaeseelandiae*) – were recorded only through incidental observations and two – little owl (*Athene noctua*) and yellowhammer (*Emberiza citrinella*) – were only recorded on the bird recorders. The remaining 24 species were all recorded in at least two separate methods. No bird species were detected only in 5MBC. The bird species found in the most habitat types was the silvereye (*Zosterops lateralis*) which was recorded in every 5MBC apart from that at Site 5 and identified in every site's bird recorder. The three rarest species were little owl, black shag and sacred kingfisher, each of which was only recorded once. The little owl was identified on the Site 2 bird recorder while the black shag and sacred kingfisher were recorded incidentally and were not associated with any of the six sites.

Table 1-2: List of all 30 species detected at Cleardale Station.

Native species are in bold, introduced species in plain text and hybrid species in italics.

Canada Goose	**New Zealand Fantail**
Paradise Shelduck	Eurasian Skylark
Grey Teal	**Silvereye**
Mallard	**Welcome Swallow**
Mallard X Grey Duck Hybrid	Eurasian Blackbird
Australasian Shoveler	Song Thrush
Black Shag	Common Starling
Australasian Harrier	House Sparrow
Eurasian Coot	**New Zealand Pipit**
Spur-winged Plover	Dunnock
Little Owl	Common Chaffinch
Sacred Kingfisher	European Goldfinch
New Zealand Bellbird	European Greenfinch
Grey Warbler	Lesser Redpoll
Australian Magpie	Yellowhammer

Potential calls from morepork (*Ninox novaeseelandiae*), New Zealand fernbird (*Megalurus punctatus*) and brown creeper (*Mohoua novaeseelandiae*) were recorded on the Site 2 bird recorder, however there was a high level of doubt with each due to either wind noise, each call only being heard once and uncertainty over the accuracy of identification. These potential calls were informally sent to New Zealand bird experts but no consensus could be reached on their identification. With this level of doubt these bird species were not included in the final results. Australian magpie (*Gymnorhina tibicen*) were also heard on the Site 2 and Site3 bird recorders but were not included in the results for these sites as the calls were distant and deemed to be outside the habitat (native bush remnant) at those sites. Common brush-tailed possums (*Trichosurus vulpecula*) were also recorded on all four of the deployed bird recorders at sites 1 to 4.

1.4 Discussion

This study measured the diversity of bird species in five different habitat types at Cleardale Station. The results obtained indicate that matagouri scrub supports the greatest diversity of bird species and is potentially the most important in terms of bird conservation, which disproves the hypothesis for this study. Conversely short tussock grassland is the least diverse in terms of diversity of bird species. However these results were taken over only a two day period and so do not account for seasonal variation, so it is difficult to say which habitat is the most important for bird conservation based on this limited time frame. The results also indicated silvereye to be the most widespread bird at Cleardale Station as it was found in four different habitat types, which fits with previous studies that have found this species to be a generalist forager (Waite, Closs, van Heezik, & Dickinson, 2012). The relatively even split between native and introduced bird species at Cleardale (14 native and 16 introduced) is likely a result of the mix of native and exotic vegetation present as native birds have a preference for native plants and introduced birds a preference for exotic vegetation (Barnagaud, Barbaro, Papaïx, Deconchat, & Brockerhoff, 2014).

As many of the habitat types were quite small in area it was difficult at times to distinguish which birds were in the relevant habitat and which were in adjacent habitat. For instance Site 4 was in matagouri scrub but was close to a pine (*Pinus* sp.) shelter belt, when analysing the Site 4 bird recordings it was impossible to tell which bird calls were coming from the matagouri and which were coming from the pine shelterbelt. This could have contributed to the matagouri habitat having the greatest apparent bird diversity. Neither Site 5 or Site 6 had a bird recorder deployed which may have meant fewer bird species were detected there compared to the sites which did have bird recorders. The smaller size of the habitats could also have artificially increased bird numbers in the habitat being measured through edge effects, where higher bird numbers are found on the edges of bush patches rather than in their centre (Barbaro, Brockerhoff, Giffard, & Halder, 2012).

For further study more comprehensive bird surveys are needed involving more than the one 5MBC at each site in this study. In particular the extensive wetland system near Site 6 needs further study including a bird recorder as wetlands often harbour secretive bird species with low detection probabilities (Steidl, Conway, & Litt, 2013). Returning to Cleardale at a different time of year would be advantageous to account for seasonal variation and to survey in different conditions as during the data collection strong winds were common and masked bird calls for both the 5MBCs and the bird recorders. Returning to Cleardale at a different time of year would also be of benefit to test whether matagouri scrub remains the most diverse habitat in terms of bird species.

Based on the results for this study the best option for increasing bird diversity at Cleardale Station is to consider that station as a whole rather than any one individual habitat. The habitat with the most bird species (matagouri scrub) from this study only had half the total species for the station as a whole, meaning protecting just that area would do little for bird diversity at Cleardale. Both remnant native vegetation and native plantings have been shown to increase bird numbers in farmland (Cunningham et al., 2008). Excluding stock from the native vegetation remnants at Cleardale and including them in a network with current and future restoration plantings would likely increase the bird diversity as a whole. Using the remnant vegetation and plantings as “core” areas to protect helps the native species that inhabit them (Starling-Windhof, Massaro, & Briskie, 2011) and increases the likelihood of beneficial species in terms of ecosystem services using these areas for shelter. In terms of species of conservation value the Rakaia River that borders that station has the most important species (wrybill and black-billed gull) and an already existing trap network to protect them. Increasing this already existing network on Cleardale Station to encompass native vegetation remnants and plantings would further protect wrybill and black-billed gulls and benefit the birds on Cleardale Station itself.

Treating the station as whole and not investing all protection into one area also decreases the chances of losing that area through tenure review or district plans (Todhunter, 2007) while not compromising the conservation value. This is an important point as it increases the incentive for farmers to implement conservation schemes on their land. If control and restoration can be implemented in this way at Cleardale Station without inhibiting the ability to farm then Cleardale would become an excellent example of a biodiversity minded farming model.

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1.6 Appendix A

Coordinates (Latitude / Longitude) for Bird Recorders

Site 1= 43°27'15.23"S 171°33'29.75"E

Site 2= 43°27'4.99"S 171°33'52.65"E

Site 3= 43°26'44.08"S 171°33'55.71"E

Site 4= 43°27'1.37"S 171°34'35.94"E

Chapter 2: Soil organic carbon levels in irrigated and non-irrigated pasture at Cleardale Station, Canterbury

Jocelyn Henderson

Abstract

Soil organic carbon plays a crucial role in soil health and therefore is vital for productivity of agricultural land. Intensive agricultural practices have led to global declines in soil carbon stocks, with subsequent impacts on productivity and the ecological and economic sustainability of the land, as well as implications for carbon sequestration. Studies investigating the effects of irrigation on soil carbon levels in New Zealand are not conclusive but suggest that long-term irrigation is linked to a decline in soil carbon levels. Testing was carried out at Cleardale Station in Canterbury, New Zealand to ascertain whether there was a difference in soil organic carbon levels in non-irrigated grazed pasture compared to pasture after nine years of irrigation. Errors during the lab analysis meant there were no viable results but on-site visual analysis of soil suggested no noticeable difference between irrigated and non-irrigated pasture. Further testing at the site would be beneficial to confirm levels of soil organic carbon as this may have future management implications for the station.

2.1 Introduction

Soil provides a range of ecosystem services that are necessary for human health and agricultural production. These services, which include carbon sequestration, nutrient cycling, water retention, food production and biodiversity, are dependent on the interaction of chemical, physical and biological soil properties and functions. Soil organic carbon (SOC) influences all other soil functions and therefore plays a crucial role in providing these ecosystem services. Higher levels of SOC are linked to improved aeration, increased water-holding and nutrient-holding capacity, and are directly linked to soil productivity (Lal, 2004). Retaining or improving soil carbon is therefore crucial to the ecological and economic sustainability of land (Shepherd, 2000), as well as being vital for carbon sequestration and climatic stability (Lal, 2004). Land use and agricultural management practices affect SOC, and globally soil carbon stocks are declining. While New Zealand soil carbon levels are generally higher than the global average, studies have shown that carbon stocks are declining in intensively farmed areas in New Zealand. International studies on the effects of irrigation on soil carbon levels show significant variation depending on climate and location, but recent studies in New Zealand have linked irrigation to declines in soil carbon stocks in grazed grasslands (Schipper et al., 2017; Whitehead et al., 2018). The aim of this study was to test levels of SOC in adjacent irrigated and non-irrigated pasture at Cleardale Station, Canterbury, to ascertain whether there was a difference in soil organic carbon after nine years of irrigation.

2.2 Background

2.2.1 Soil Ecosystem Services

Soil provides various ecosystem services that are vital to human life and agricultural productivity. It is a keystone of biodiversity, hosting the largest diversity of organisms on land (Smith et al. 2015), and plays a key role in nutrient and water cycling, water retention, supporting food production, and regulating crop pollination, pest and disease control (Adhikari & Hartemink, 2016). It is the largest terrestrial sink of carbon and therefore maintaining and improving soil carbon levels is necessary for climatic stability. There are several forms of soil carbon but soil organic carbon (SOC), which is a component of soil organic matter (SOM), makes up the greatest proportion of carbon in New Zealand soils (Tate et al., 1997). SOC is a key determinant of soil health and subsequent agricultural productivity, with increases in SOC linked to higher water retention (Rawls et al., 2003) and less vulnerability to wind erosion (Shepherd, 2000).

2.2.2 Agricultural Practices and Soil Carbon

Conversion of forest to cropping and pasture have led to a global decline in soil carbon stocks (Whitehead et al., 2018). In New Zealand, agricultural land is predominantly grazed pasture, and most grasslands have moderate to high soil carbon stocks in the surface layers (Whitehead et al., 2018). While grasslands tend to show less decline in soil carbon stocks than under cropping, recent studies have shown that carbon stocks are decreasing in intensively grazed grasslands (Schipper et al., 2017).

Carbon stocks in soil depend on the net balance of inputs (plants and manure) and outputs (respiration, leaching and exports of animal produce) (Schipper et al., 2017). Management practices such as fertiliser application rates, stocking rates, frequency of soil cultivation or irrigation affect carbon stocks, but specific causes and effects are difficult to isolate (Schipper et al., 2017). International studies have shown that the addition of feed imports, fertilisers and the application of manure and effluent can increase soil carbon, particularly in degraded soils, but there is a lack of studies specific to New Zealand and therefore the response of New Zealand soils is uncertain (Whitehead et al., 2018). Other research has suggested that fertilisers and agrochemicals adversely affect soil biodiversity, which in turn has a negative effect on carbon and nutrient cycling (Thiele Bruhn et al., 2012). There is evidence that biodiversity increases SOC in grasslands as high plant diversity elevates carbon inputs and increases soil microbial community diversity and activity, though further studies are necessary to better understand these mechanisms (Chen et al., 2018).

Overall, management systems that add biomass to the soil, minimise soil disturbance, conserve soil and water, improve soil structure, and enhance diversity of soil fauna contribute to increasing levels of soil carbon (Lal, 2004). Increasing soil carbon stocks has often been seen as requiring trade-offs with other outcomes like increasing production (Whitehead et al., 2018). However, the growing interest in regenerative farming principles may signal a shift towards management practices that appear to meet the dual purpose of minimising inputs while enhancing soil functions and biodiversity, and therefore increasing productivity. These practices include minimising soil disturbance, planting cover crops, nutrient management, manure application, improved grazing, and efficient irrigation (Lal, 2004).

2.2.3 The Effects of Irrigation on Soil Carbon

The relationship between irrigation and soil carbon stocks varies depending on climate, soil type and management practices. Soil C stocks tend to increase with water availability in natural environments, as this leads to increased plant growth and inputs to soils (Schipper et al., 2017). In keeping with this hypothesis, irrigation has been linked to higher levels of soil organic carbon in arid or semi-arid regions, as increased water availability improves plant growth and increases inputs (Trost et al., 2013). However, less is known about how irrigation affects areas with more precipitation and higher initial soil organic carbon content (Trost et al. 2013).

There is a lack of comprehensive data on irrigation and soil carbon levels specific to New Zealand, where the climate is generally humid and soil carbon stocks are relatively high compared to overseas agricultural soils. However, several recent New Zealand studies have linked irrigation to a decline in soil organic carbon, though the processes and long-term trends are still unknown (Schipper et al., 2017; Whitehead et al., 2018). Mudge et al. (2016) found in a comparison of 34 paired irrigated and non-irrigated sites across New Zealand that irrigated pastures had significantly less soil carbon than adjacent non-irrigated pastures. Both Kelliher et al. (2012) and Condron et al. (2014) (cited in Schipper et al., 2017) concluded that irrigation substantially increases carbon loss through soil respiration. Houlbrooke et al. (2008, cited in Schipper et al., 2017) found that sites that had been irrigated for more than five years had lower soil carbon than sites than those that had been irrigated for less than five years.

While some studies that have not reported a significant difference between irrigated and non-irrigated sites, in a review of carbon change in New Zealand grazed grasslands, Schipper et al., (2017) concluded that overall irrigation was linked to a decline in soil carbon levels, though the causal factors of this loss are not yet clear. Based on the literature, it was expected for this study that soil carbon levels would show no significant difference or be slightly lower in irrigated pasture.

2.3 Methodology

2.3.1 Study Site

The study took place at Cleardale Station, a 1600 hectare farm situated alongside the Rakaia River in Canterbury, in the Mt Hutt ecological district. The station, which ranges from 300m -700/800m altitude, comprises intensively grazed river flats and foothills. The area has relatively high precipitation rates of 1000mm per year, with prevailing westerly winds that commonly reach up to 100km/hr. This study focuses on the alluvial river terrace flats (Fig. 1) on the southern side of the river where loess (wind-blown soil) has accumulated from the riverbed. The soil comprises clay, silt and loam.

Figure 2-1: The farmed river terrace flats at Cleardale Station

2.3.2 Fieldwork

Soil samples were taken from two paddocks at Site A and two paddocks at Site B (see Fig. 2.). The two sites were chosen by the farmer for comparison as they both offered adjacent irrigated and non-irrigated pastures. The sites were situated in close proximity to one another on the southern terraces alongside the river and were similar in terms of altitude, aspect, soil type and management regimes. Fertiliser had been used at both sites (phosphate applied in split dressings, nitrogen added in spring and autumn, and low amounts of capital lime added). Both sites were grazed rotationally with cattle in spring and sheep from summer to autumn, and were not usually grazed through the winter. During the time of sampling the irrigated paddocks were grazed by cattle, while the non-irrigated paddocks were ungrazed. Both irrigated sites had been irrigated for nine years. The pasture at Site A was clover mix as originally planted, while Site B was transitioning to lucerne pasture, and direct-drilling was used at both sites.

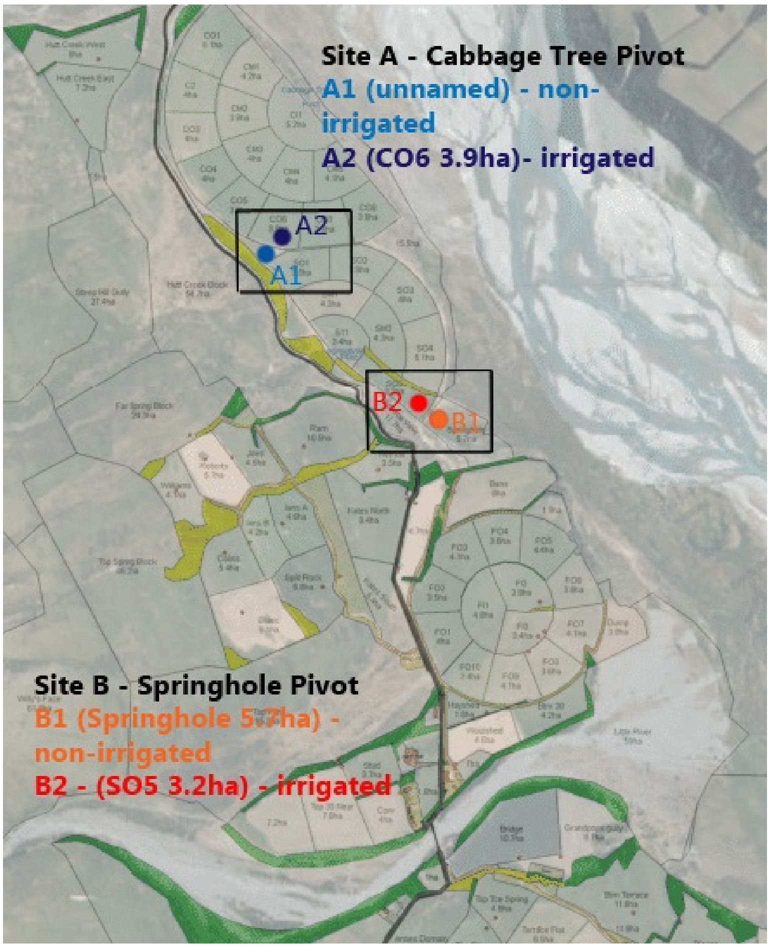

Figure 2-2: ***Cleardale Map showing sampling sites.***
A1 shows the first non-irrigated site while A2 is irrigated. B1 marks the second non-irrigated site and B2 marks the second irrigated site.

The soil sampling occurred in mid-March over the course of one day. Three sites were chosen at random in each paddock. A spade was used to expose the soil profile to a shallow depth and photos were taken for visual comparison of the soil profile. A hand auger was used to take two samples from each site at 0-7.5 cm and 7.5-15 cm. A total of 24 soil samples were taken for lab analysis.

2.3.3 Soil Analysis

The soil was assessed in two ways: a visual analysis based on photos of the soil profile and laboratory analysis of organic carbon. Many physical and biological soil properties show up as visual characteristics, so visual indicators can therefore provide an effective way to immediately gain an idea of soil quality (Shepherd, 2000). Due to time limits, visual analysis was done from photos so focuses on soil colour. Darker soil indicates a higher proportion of organic matter, while greyer soil suggests poor aeration (Shepherd, 2000). Topsoil colour varies between soil types but as soils were similar at each site, trends can be identified.

The samples were analysed for soil organic carbon using Loss on Ignition (LOI), a widely used method for measuring organic matter content and soil organic carbon (Hoogsteen et al., 2015). LOI measures SOM and SOC as the weight loss of a dry soil sample after combustion in a furnace.

2.4 Results

2.4.1 Visual Assessment

Visual comparisons suggested that there was not a significant difference in soil carbon between irrigated and non-irrigated sites. Exposure of the shallow soil profile showed similar colour, soil structure and root penetration in both irrigated and non-irrigated pastures at both sites.

At Site A the soil profile did not show a significant difference in colour or structure (Fig. 3.) Site A pasture was a rye/clover mix and there was limited root penetration of the relatively compact soil. Both soils are a similar brown colour though the image from the non-irrigated site does show more colour gradation, with paler soil at lower depth than the irrigated site where soil colour remains consistent. At Site B (Fig. 4.), the lucerne pasture, the soil profile at the irrigated site (B2) appears slightly darker than that of the non-irrigated site, though there is a not a significant difference.

Figure 2-3: Soil Profiles at Site A.
On the left: similar soil profiles of non-irrigated pasture at Site A1 on the left and irrigated pasture at Site A2 on the right, though the non-irrigated site shows paler soil at lower depth.


Figure 2-4: Soil Profiles at Site B.
Non-irrigated soil (B1) on the left and irrigated soil (B2) on the right. Both soil profiles are similar in structure and colour though B2 is slightly darker.

2.4.2 Analysis by Loss on Ignition

Due to a labelling error, the majority of the labels were destroyed in the furnace and there were therefore very few results. Table 1 shows SOM and SOC content of the few samples that survived with labels intact.

Table 2-1: Total Organic Matter & Organic Carbon by Loss on Ignition

Sample serial No.	Sample Label	Soil Wt (g)	105° oven-dried soil Wt (g)	550° ashed soil (g)	LOI (%) or SOM (%)	SOC (%)
1		10.4562	8.2955			
2		11.6301	9.0094			
3	A1 Non-irrigated 2 (0-7.5 cm)	10.2875	9.1049	6.9519	23.65	13.75
4	B2 Irrigated 3 (7.5-15 cm)	10.6276	8.6426	7.8623	9.03	5.25
5		10.7784	9.4075			
6		11.2040	9.5815			
7		10.6437	9.1747			
8		11.0745	8.6747			
9	A2 Irrigated 3 (0-7.5 cm)	11.1984	8.3326	7.5960	8.84	5.14
10	A2 Irrigated 3 (7.5-15 cm)	11.0262	8.7464	8.3315	4.74	2.76
11		11.3163	9.6019			
12		10.9814	8.9860			
13		11.2913	9.1928			

14		10.2650	9.3253			
15		11.2692	10.2503			
16		11.5510	10.6896			
17		10.9652	9.6523			
18	? Non-irrigated 3 (7.5-15 cm)	11.3986	9.2354	8.7035	5.76	3.35
19		10.8989	9.2347			
20		11.2755	7.6851			
21		12.3613	10.9870			
22		13.2622	11.8660			
23		11.1743	9.1313			
24	? Non-irrigated (7.5-15 cm)	12.3616	8.3253	7.5065	9.84	5.72

2.5 Discussion

The lack of results due to samples lost in the LOI process mean nothing can be concluded from this study. The results show high variability in SOC ranging from a low 2.76% SOC to a high 13.75% but there are too few results to draw any inferences from these data. To put these numbers in a broader perspective, mean soil carbon concentration to a depth of 0.3m in New Zealand grasslands is estimated to be at 3.5%, which is moderately high (Whitehead et al., 2018).

It was expected that there would either be no significant difference, as the sites are in an area of relatively high precipitation at 1000mm per year and therefore irrigation is unlikely to lead to significant increases in biomass, or that there would be lower levels of SOC in irrigated sites. The visual analysis of the soil did not suggest a significant difference between soil organic carbon in irrigated and non-irrigated sites. However, while visual analysis can be a useful indicator of soil quality and carbon levels, it is not conclusive.

A limitation of the original study is the small sample size of three spots chosen for testing in each of the four paddocks due to a lack of time and pre-planning. Therefore, even had there been lab results they would not have been conclusive for the whole area, as there can be significant variability of SOC within a paddock (Schipper et al., 2017), and more samples across a wider area should be taken in each paddock to build a more reliable picture of SOC levels. Repeated measuring could show changes over time, but SOC is a rapidly moving cycle so levels are likely to vary from year to year based on climatic effects and management decisions (Schipper et al., 2017). Sampling a specific site multiple times over a set period can provide more insight into drivers of change (Schipper et al., 2017).

2.6 Conclusion and Further Research

Conventional agricultural practices can lead to a decline in soil carbon stocks with consequences for biodiversity, land productivity and carbon sequestration. The processes of how irrigation affects soil carbon in New Zealand is still not fully understood but studies have shown that it is likely that irrigation will lead to a decrease in soil carbon over the long-term. A comparison between two paired sites at Cleardale Station did not show any conclusive results but visual analysis suggested there was no significant difference in SOC. Ongoing testing with a larger sample size would build a more comprehensive picture and allow the farmer to measure changes in SOC over time, which may have implications for future land management practices to prevent loss of SOC.

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Chapter 3: **Fire Management at Cleardale Station Using Green Firebreaks**

Tanmayi Pagadala

Abstract

Cleardale station is a high-country farm located in Rakaia, New Zealand and owned by former Lincoln University student and a past Chair of the Lincoln University Foundation, Ben Todhunter. It is a 1600 ha sheep and beef farm, with outstanding landscapes around it, such as the Rakaia River, attracting many tourists. As part of the ECOL 609 Conservation Biology course at Lincoln University, a three-day field trip took place, wherein I looked into fire management on the farm through the use of green firebreaks that consist of native New Zealand species. This report looks at the purpose of green firebreaks, how fire weather is expected to change in future, the connection between fire risk and biodiversity, as well as some recommendation as to what native NZ species may be used as green firebreaks.

Due to human-induced land use and climate change, global temperatures are expected to rise, with severe fire weather predicted for New Zealand. Pre-historically, natural fire activity in New Zealand was relatively low, which may mean that many native NZ plants may not possess the required traits to withstand or recover after a widespread fire. Moreover, the South Island high-country is already facing a decline in ecological values due to land degradation, making it easier for invasive species to take over. This not only threatens the biodiversity of the landscape, but also alters existing fire regimes. Green firebreaks are strips of low flammability vegetation which are placed around a landscape in order to avoid a widespread fire. If these strips are made of native New Zealand species of low flammability, they will not only aid in fire management, but may also combat the decline in native biodiversity.

A section of Cleardale land was used to survey different species present, wherein the species were photographed for identification as well as noting down the location of those species. Identified species were then literature-reviewed for their flammability levels. A total of 11 species were identified, wherein 4 were native and 7 were exotic. Many of these species haven't yet been tested for their flammability, with high variability in level of flammability between the native species.

Green firebreaks may be one of the many unique opportunities that can be used to enhance high country values. Further research in this area of fire ecology in New Zealand will enable New Zealand landowners and farmers to prepare for an unpredictable future. Moreover, with the country already facing a concerning native biodiversity threat, implementing native species in green firebreaks may be profitable to the environment.

3.1 Introduction

3.1.1 About the study site

Cleardale is a high-country station, which is situated up the Rakaia Gorge, in Canterbury, New Zealand (Figure 1a and 1b). The station is currently 1600 hectares of freehold land owned by Ben Todhunter. Most of the land is spread over 300-700m altitude above sea level and consists of intensive flats and extensively farmed foothills. The station mostly consists of both sheep and beef farms, with 5,500 ewes and 300 breeding cows, as well as irrigation fields, which occupy 200ha of the 1600. The farm typically runs Merino, English Leicester, Half-bred, Quarter-bred and some Angus studs. Moreover, 80 ha of the land is used for cereals, grazing dairy heifers and finishing cattle. The station receives a 1000ml rainfall and typically experiences 100-240k/h winds, which usually tend to be westerlies.

(a)

(b)

Figure 3-1: ***Location of Cleardale Station, above Rakaia Gorge, Canterbury.***
(a) Image retrieved from Google Earth. (b) Map by Di Lucas (2019), retrieved from ***https://www.dropbox.com/sh/3y0k0t6d1bixvit/AAB4c1DLvHUxlUUaB_zL2nKga?dl=0***

3.1.2 Flora and Fauna

Much of the station consists of matagouri (*Discaria toumatou*) and tussocks (Poaceae family), wherein the tussocks typically dominate at higher altitudes. Matagouri was found to be at high densities in some areas. The station also has patches of kowhai (*Sophora microphylla*), introduced sweet briar (*Rosa rubiginosa*) and a bit of kanuka (*Kunzea ericoides*). There is also some flax (*Phormium tenax/ Phormium colensoi*), NZ cabbage (*Cordyline australis*), some *Pittosporum* species, totara (*Podocarpus totara*), and some *Coprosma* species (e.g. *C. propinqua*). Gorse (*Ulex europaeus*), an invasive species is also common in the station. There were also some hares and deer observed, which pose a problem to plant species as they tend to graze frequently.

Recently, the station has been facing an increased weed problem, as well as some mammal pests (rabbits, hares and hedgehogs). Species of the Buddleia family, also known as summer lilac, *Cotoneaster* spp., Californian thistles (*Cirsium arvense*) and Elderberry (*Sambucus nigra)* are some of the problematic weeds. Buddleia does well in shingles, while *Cotoneaster* seems to be taking over the farmland. Moreover, the farmers are also faced with matagouri and kowhai management issues. Matagouri in Cleardale has usually been cleared by cutting it, as burning it wasn't effective, and is often hard to do so. This is because they have a rich seed source and a high re-sprouting ability, enabling them to grow back quickly (Daly, 1969). This might also be why matagouri can be found in high densities in some parts of the station. The same applies, for gorse, an invasive species which, if not looked after can have drastic effects on biodiversity.

3.1.3 Defining green firebreaks and its purpose

Wildfires have been a common occurrence in recent times in many parts of the world, due to human-induced climate change and land-use changes (Bowman et al. 2017). Though New Zealand hasn't experienced much natural fire activity (Guild & Dudfield, 2009; Perry et al. 2014), predictions of severe fire weather and danger for the country (Pearce & Clifford, 2008) emphasizes the importance of fire management now more than ever. Plant flammability plays an important role when assessing the intensity of fires. Different species of plants differ in their flammability, wherein areas of less flammable species can avoid or slow down the spread of wildfires (Curran et al. 2018). This leads to the concept of 'green firebreaks', wherein strips or layers of plant species with low flammability are strategically placed around or across a landscape (Curran et al. 2018; Cui et al. 2019).

Plant flammability comprises four main components: ignitability, combustibility, sustainability and consumability (Anderson, 1970; Wyse et al. 2016). When measuring plant flammability, all or some of these components may be quantified using various methods. Plant flammability can also be measured using different parts of the plant such as leaves or needles, twigs (Owens et al. 1998; Dimitrakopoulos & Papaioannou, 2001; Kane et al. 2008), litter (Cornwell et al. 2015) or more recently, using whole shoots or whole plants (Wyse et al. 2016). Moreover, some functional traits that determine the flammability of plants include: moisture content, retention of dead material and unstable organic compounds (Padullés Cubino et al. 2018).

The structure and density of green firebreaks play a crucial role in its effectiveness (Cui et al. 2019). Past studies have shown the firebreaks to be either single-layered, wherein it typically consists of one species, particularly a tree species, or for it to be multi-layered which comprises a mixture of tree, shrub or herbaceous species (Cui et al. 2019). Positioning of a green firebreak is also equally important as the aim of a firebreak is to isolate a fire and prohibit it from spreading (Cui et al. 2019). Moreover, using native species to implement green firebreaks may be a good conservation tool (especially in NZ), as not only does it reduce the risk of fires spreading across the landscape, it may also contribute towards biodiversity by providing food for native fauna, as well as increasing their habitat and dispersal opportunities (Curran et al. 2018). Even though NZ high country has not seen many wildfires in the past, due to climate change contributing to higher temperatures and drier conditions, the possibility of fires is expected to rise (Curran et al. 2018; Cui et al. 2019), making the occurrence of fires in the high country a 'when' instead of an 'if'.

3.1.4 New Zealand High-Country and flammability of its biodiversity

New Zealand high country mostly consists of tussock grasslands, specifically the endemic snow tussock, *Chionochloa rigida*, which is a highly flammable species (Padullés Cubino et al. 2018). Much of NZ's native flora have evolved at times of uncommon fire activity, so it makes sense for them not to possess low flammability traits. However, invasive grasses and plants are on the rise which have the ability to alter the functioning of whole ecosystems (Wyse et al. 2018). Specifically, invasive plants that alter the ecosystem through altering fire regimes are the most significant (Wyse et al. 2018). A few examples of exotic invasive species are *Cytisus scoprius, Hakea sericea, Ulex europaeus* and *Pinus radiata*, wherein *H. sericea* and *U. europaeus* were found to be the most flammable (Wyse et al. 2018). However, many invasive species tend to be low in flammability such as *Crepis capillaris*, *Pilosella officinarum* and *Hypochaeris radicata* (Padullés Cubino et al. 2018). While this low flammability trait may encourage more invasions to occur, and offer an advantage in terms of decreasing the probability of a fire from spreading, it is a huge disadvantage to native and indigenous species. Moreover, a recent study by Wyse et al. (2018) has shown that the intensity of combustibility and ignitability by two different species of plants is determined by the higher flammable species of the pair. This accentuates the fact that nature is complex and that everything in nature is inter-related/connected. Such complexity paired with climate change and increased global temperatures makes fire management more challenging.

3.1.5 Purpose of study

While there are a few studies suggesting that fire may have a positive contribution towards biodiversity and conservation (Curran et al. 2018), land management policies are sensitive to use of fire, especially in areas that have high conservation issues. New Zealand high country consists of some of the world's most unique landscapes, majority of which have been cleared by fire for pastoral and agricultural uses since the 1900's (Brower et al. 2020). Recently, the South Island high country has seen an increase in invasive animals and plants which is problematic for native fauna and flora, while also interfering with the high-country ecosystem services (Brower et al. 2020). Additionally, the land has been degraded to such an extent that any further development on land in the high country will contribute to a concerning decline in ecological values (Brower et al. 2020). While a recent review of the high country by Brower et al. (2020) have looked at issues like tenure review and Crown pastoral leases while outlining and acknowledging some ecological problems, fire management was something they did not explore, let alone mention it. Hence, through the ECOL609 Conservation Biology course, I have explored the area of fire management in NZ high country farms, especially through the use of green firebreaks with native NZ species, given that much of NZ flora evolved in an environment without frequent fires. This may help to bring together the idea of combating native biodiversity loss, as well as protecting the land.

This paper seeks to address the following questions:

- What comprises the plant biodiversity at the study site in Cleardale?
- Of these species, how many of them have been tested for flammability in New Zealand already?

- How many native NZ species found in the study site are of low flammability?
- Based on your analysis, what species may be recommended to be used as green firebreaks at Cleardale? And where might you place them?

3.2 Methods

3.2.1 Study site

While the study is based on Cleardale Station as a whole, a specific study site was chosen as a representative of the station, which were the sites at and around the Cleardale Hydro Power Station (see Figure 2).

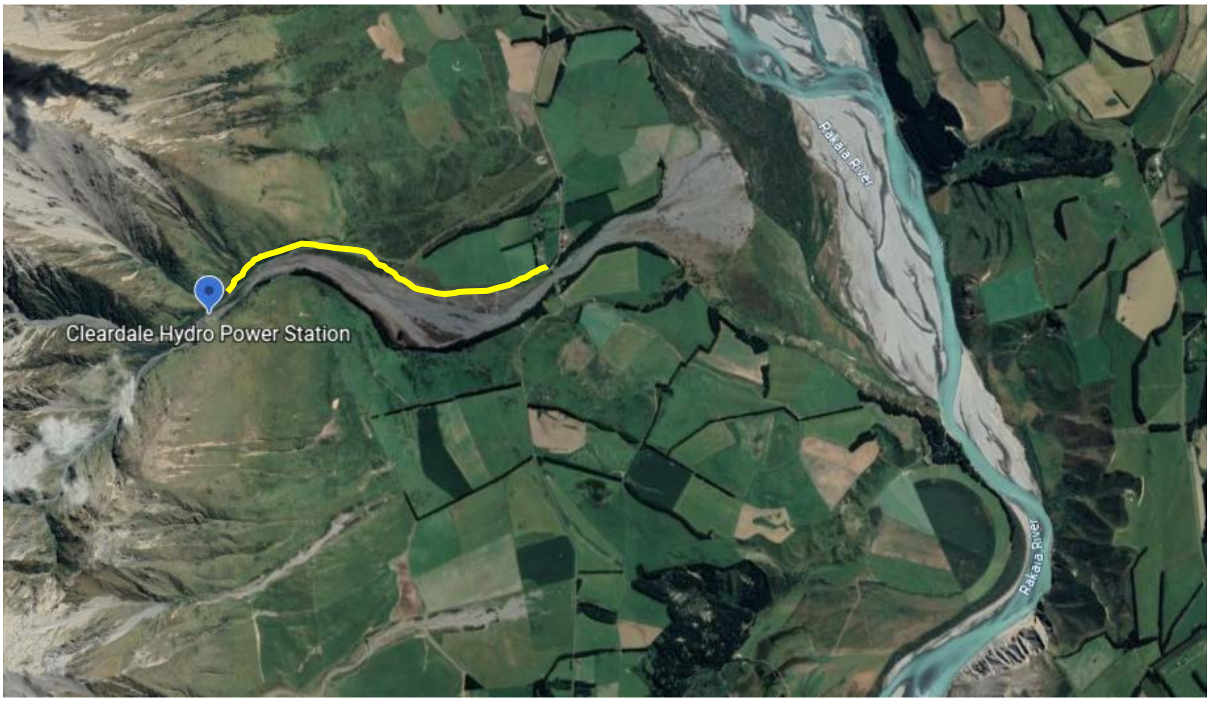

Figure 3-2: Study site location by the Cleardale Hydro Power station.
Yellow line indicates the path through which plant surveying and photographing were done. Image retrieved from Google Earth on 30th May, 2020.

3.2.2 Process

This study comprised a combination of surveying plants, literature review, interviewing, taking photographs of plants and using those photographs for species identification. Information was gathered in the following ways:

- Observing, surveying and photographing different species found at the study site (see Figure 2) on a two-day field trip to Cleardale Station, Rakaia in March 2020. I also noted down the longitude and latitude of where some of the species were located.

- Interviewing the farm owner, Ben Todhunter, and his wife, Donna Field, regarding current fire management strategies and procedures on the farm as well as current restoration efforts (See Appendix 1 for the list of questions asked).

- Photographs of the different plant species were then uploaded into a species identification application known as ‘iNaturalist’, to help identify the respective species.

- Once the names of the different species were acquired, an extensive desk-top literature review was undertaken to figure out if the species found were tested for flammability in New Zealand (see References).

The species identified were then split into two categories: Native and Exotic. Furthermore, five categories were used in order to determine the different levels of flammability: Very Low, Low, Moderate, High and Very High (ref, also see Table 1).

3.3 Results

3.3.1 Main observations and results

A total of 11 species were identified, wherein 4 species were native, while 7 were exotic. 4 of the 7 exotic species were found to yet to be tested in NZ for their flammability, while the species of the same genus of the other two exotic species were tested for their flammability, but not the particular species (see Table 1).


(a) Black Poplar (*Populus nigra*)


(b) Great mullein (*Verbascum Thapsus*)


(c) NZ Cabbage Tree (*Cordyline australis*)


(d) Tutu (*Coriaria*)


(e) Red Clover (*Trifolium pratense*)


(f) Peachleaf Willow (*Salix amygdaloides*)


(g) Snow tussock (*Chionochloa rigida*)


(h) Common yarrow (*Achillea millefolium*)


(i) Matagouri (*Discaria toumatou*)

Figure 3-3: ***Species that were photographed on site at Cleardale, Rakaia. All images taken by Tanmayi Pagadala on March 16, 2020.***

Table 3-1: ***Flammability levels of the different species found on study site at Cleardale Station, Rakaia. (Cui et al. 2020)***

Species		**Flammability Level**
Native	NZ Cabbage Tree (*Cordyline australis)*	**Low/Moderate**
	Tutu (*Coriaria arborea)*	**High**
	Matagouri (*Discaria toumatou)*	**Moderate/High**
	Snow tussock (*Chionochloa rigida*)	**Very High**
Exotic	Black Poplar (*Populus nigra*)	**Low**
	Red Clover (*Trifolium pratense*)	This specific species is yet to be tested, but may be **Low** (based on *T. arvense* and *T. repens*)
	Peachleaf Willow (*Salix amygdaloides)*	This specific species is yet to be tested, but may be **High** (based on *S. fragilis* and *S. matsudana*)
	Viper's-bugloss (*Echium vulgare*)	Yet to be tested in NZ
	Great mullein (*Verbascum Thapsus)*	Yet to be tested in NZ
	Common yarrow (*Achillea millefolium*)	Yet to be tested in NZ
	Creeping thistle (*Cirsium arvense)*	Yet to be tested in NZ

3.3.2 Information from interviews

From the interview with the farm owner, Ben Todhunter, and his wife Donna Field, it was found that green firebreaks had never been used as a fire management tool in the past (see Appendix 1 for interview questions). Current fire management strategy on the farm mostly consists of keeping the grazing height short to avoid fires. While a large fire is devastating for the whole landscape, Ben mentioned that the greatest danger would be around the grazing areas, where people were working and along the road corridors. Moreover, the main ignition sources on the farm are either through people camping close by or the use of farm machinery.

3.4 Discussion

Through this study and the fieldwork carried out at Cleardale Station, I have found that the number of exotic species seem to be greater than the number of native New Zealand species on the farm. This may emphasise the importance of biodiversity conservation in high-country landscapes of NZ, given that a concerning amount of land has already been degraded, and that the landscape is losing many of its ecological values (Brower et al. 2020). However, since this study is based on just one study site, there might be some species that I may have missed observing, like the ones mentioned in the Introduction of this report (see Section 1.2). While all the native species identified in this study have been tested for their flammability, the majority of the exotic species found in this study do not seem to be tested for their flammability in New Zealand yet. This brings to light the importance of testing flammability of exotic species in NZ, as the level of flammability may differ between countries. For example, Viper's-bugloss (*Echium vulgare*) or the blueweed, (see Figure 3j), did not burn well (i.e. low flammability) in a burn trial in Montana as the plants did not dry out very well, and had to be air dried for several days prior to the burn trial before it burned successfully (Graves et al. 2010). We may get different results if the trial was carried out in another country, wherein the plant may have been grown under different conditions.

Typically, a common conservation objective for a distinct management area is to evade population extinctions, due to the consequence of an adversative fire regime (Bradstock et al., 1995). However, when thinking about fire management and biodiversity, there are many factors that come in to play apart from plant flammability. Many of these factors have not been considered in this study, given the time constraints at the field trips, and not being able to carry out field work for longer in order to gain a better understanding, due to the global pandemic, COVID-19. Moreover, much research regarding fire management strategies for conservation has heavily focused on vegetation and plant species, as it appears that understanding is profound in the area of vascular plants (Driscoll et al. 2010). For the rest of this report, I will discuss other factors that affect a fire, how biodiversity can play a role in fire management through the use of green firebreaks, ignition sources and how a fire can be prevented from moving across the landscape. I will then conclude with some recommendations regarding fire management and what species may be used as green firebreaks on Cleardale.

3.4.1 The connection between fire risk, fire regimes, biodiversity and climate

3.4.1.1 Fire regimes

Fire regimes differ between different geographical areas and with time. A fire regime is described as "a history of fire events", which is "important with respect to environmental effects" (Gill & Allan, 2009). Although, Gill (1975) defined a fire regime as a combination of fire frequency, intensity, seasonality of occurrence and the type of fire (i.e. if the fire is above or below the ground). This tells us that an occurrence of widespread fire is not only dependent on present climatic conditions and plant characteristics, but also the landscape's experience with fire in the past. Pre-historically, natural fire activity was relatively low in NZ and even when they did occur, they were mostly in lowland wetland habitats (Guild & Dudfield, 2009; Perry et al. 2014). Given that much of NZ's native flora evolved at times of uncommon fire activity, it may imply that they do not possess low flammability traits or traits that allow them to persist after a fire. This pattern can be observed in my results, wherein only one of the four native species found is of low flammability. Furthermore, in a study by Teixeira et al. (2020), the rate of re-sprouting (a vital trait that allows plants to persist post-fire) was found to be weak in native species. Driscoll et al. (2010) suggests that, information regarding a species' ability to persist in an area when under different fire regimes, how the species responds to fires across a range of sites through a region, as well as its capacity to disperse and establish is required in order to understand how fire regimes can affect the extinction risk of a species.

3.4.1.2 Role of wind in a fire

Climate change in New Zealand is predicted to result in drier, windier and warmer conditions, as well as causing increased drought periods (Pearce et al. 2011), with harsher conditions towards the east of the country. Wind can play a big role in fire intensity and spread, and is crucial to consider when assessing fire management strategies in Cleardale, as gale force north-westerly winds are fairly common in Canterbury (Jane, 1986). As mentioned earlier, Cleardale typically experiences 100-240 km/hour winds on average, with warm and dry westerlies being a common occurrence. In the area of fire ecology, wind is often referred to as 'ambient wind' and it supposedly has two contradictory effects on fire: it either increases fire severity by contributing more oxygen, or it cools a fire by eliminating and diluting combustible gasses (Chen et al. 2008). It is widely assumed that the rate of spread of a fire increases when a wind is present, but the effects of wind on a spreading fire is not well understood. Nevertheless, some studies show that warm and dry north-westerly winds may cause extreme fire danger (Sharples et al. 2010). A possible reason for this may be that when winds blow from the north or northwest directions, there is a sudden increase in temperature and a drop in humidity, which favour a widespread fire (Sharples et al. 2010). This may be alarming regarding fire danger for Cleardale, given that the farm regularly experiences north-westerlies.

3.4.1.3 Fire spread

Fire spread is influenced by many factors. While it is important to consider the flammability of individual species, fire spread is often influenced by the composition and structure of species in the whole community (Pausas et al. 2017). Moreover, fire spreads faster when there are slopes on landscapes, wherein the fire moves faster up slopes partially due to gravity and geometry (Beer, 1991). Multiple ignition sources may also contribute to fire spreading across a landscape (Gill & Allan, 2009). Additionally, wind direction and speed can also play a significant role in the spreading of fire, wherein multiple studies have shown that drier and faster winds contribute to larger fires (Gill & Allan, 2009; Sharples et al. 2010). However, limited information is available regarding the processes behind the spread of fire, as it is yet to be fully understood (Finney et al. 2013).

3.4.1.4 Ignition Sources at Cleardale

From my interview with Ben Todhunter (farm owner), and his wife Donna Field?, it is understood that Cleardale hasn't experienced any catastrophic fires in the past. Common ignition sources on the farm are all human-related such as farm machinery, vehicles and cigarette butts.

3.4.1.5 Biodiversity – does it really increase or decrease the risk of fire?

In future, fire regimes are not only expected to be affected by climate change, but also by human population, land use, habitat fragmentation, change in distribution of native plants and the spread of naturalized exotic plants (Gill & Allan, 2009). The last two points made are of importance in regards to this report and my study. Other studies have also shown that invasive species are capable of changing flammability by altering fuel continuity, causing the fires to spread into areas which might otherwise be spatially isolated (Bowman et al. 2014). However, many invasive species found in NZ are of low flammability, even though I wasn't able to identify them on the study site. For example, Padullés Cubino et al. (2018) found that exotic species such as *Crepis capillaris*, *Pilosella officinarum* and *Hypochaeris radicata* found in temperate grasslands in NZ, were of low flammability and contributed to a decrease in community-level flammability. This poses the question: does biodiversity really increase or decrease the risk of fire? Biodiversity is believed to enhance ecosystem functioning, and for this to occur, it needs to involve a range of different species, not just native species. While this may be true, some exotic and invasive species may instead disturb an already well-functioning ecosystem. One such species is Gorse (*Ulex europaeus*), where it has been reported as a very flammable species in many studies (Wyse et al. 2016; Pearce, 2017; Wyse et al. 2018). For example, in the recent fires that occurred on the Port Hills, Christchurch in 2017, regenerating native scrub and forests were found to be less flammable, whereas gorse scrub "contributed significantly to fire spread" (Pearce, 2017). This species is abundant around Cleardale, posing implications regarding fire danger on the farm. Furthermore, Cleardale is also faced with high presence of matagouri (*Discaria toumatou*) which is known to be either of moderate or high flammability (Cui et al. 2020), but not enough of Kowhai (*Sophoro microphylla),* which is of low flammability (Cui et al. 2020). The understanding between fire risk and biodiversity is further complicated by a finding that flammability in a species mixture is driven by the most flammable species in the mixture (Wyse et al. 2018), which may mean that species of low-flammability may not have any significant effects on suppressing the fire. Hence, it is hard to say if biodiversity increases or decreases fire risk.

3.5 Recommendations to the farmer

Climate change is expected to change the fire regimes, extend fire seasons and increase fire occurrence in boreal and temperate regions around the globe, including New Zealand (Flannigan et al. 2009). This means that New Zealand may be faced with wildfire management issues in the future due to the lack of experience. Hence, it is crucial that property and farm owners, conservationists and fire researchers begin to factor in fire management strategies such as the use of green firebreaks when designing landscapes.

The weeds and invasive species (see Section 1.2) on Cleardale are something that need immediate action. Firstly, I would recommend that an extensive survey of the flora and fauna be done in Cleardale. This would give us a clearer idea of the status of native species, weeds and the most problematic invasive species. Moreover, it would give us an indication of any threatened or endangered species that might need our attention first. For example, gorse is a common occurrence in Cleardale, and is also one of the 100 world's worst invasive species (Mandák & Pyšek, 2001). Managing this species via collaborating with organizations such as the Department of Conservation (DOC), will aid in protecting plant biodiversity on the farm. Controlling weeds such as thistles and matagouri through a combination of herbicides and pasture management strategies will further help in protecting biodiversity. Additionally, controlling the spread of invasive species will prevent major alterations to existing fire regimes. Also, future researchers could look into testing the flammability of species identified in Cleardale, that are yet to be tested, enhancing the flammability knowledge of species found in New Zealand.

3.5.1 Potential green firebreaks species

While the species that were identified on Cleardale were not all of low flammability, one native species that may be used as a green firebreak is the Cabbage Tree (*Cordyline australis*). Nevertheless, some past studies have found a few native NZ species to be of low to moderate flammability, which may be used in Cleardale. They include Karamū (*Coprosma robusta*), South Island kowhai (*Sophora microphylla*) flax (*Phormium tenax*) boradleaf (*Griselina littoralis*) and Five-Finger (*Pseudopanax arboreus)* (Wyse et al. 2016). See Appendix 2 for a list of other native NZ species of low flammability from a recent study.

3.5.2 Structure and positioning of the green firebreaks

Highest fire danger at Cleardale seems to be around the grazing fields, areas where people work and along the road corridors, according to the interview with the farm owner, Ben Todhunter. I would recommend green firebreaks which are multi-layered, wherein they consist of a combination of tree, shrub and herbaceous species, as they have been established to be more effective than single-layered firebreaks (Cui et al. 2019). It is also recommended from past studies that green firebreaks are mostly effective when sparse in structure, as they reduce the occurrence of “spot fires” (Cui et al. 2019). Perhaps, Ben could look into using a combination of some of the native species listed in Appendix 2 to establish potential green firebreaks at Cleardale. Placing them along the road corridors may be helpful in stopping any fires from moving across the landscape and on to the farm. This may prevent any property damage or damage to animal and human life on the farm. Moreover, placing green firebreaks consisting of attractive native NZ flower species such as Hebe (*Hebe salicifolia*) and Kowhai (*Sophora microphylla*) around pasture, will help attract pollinators and increase pollination of crops.

3.6 Conclusion

With wildfires expected to rise and severe fire weather predicted for NZ (Bowman et al. 2017; Pearce & Clifford, 2008), research in fire management and mitigating fire risk is of great importance now more than ever. Implementing green firebreaks with native NZ species will not only contribute to preventing a widespread fire, but may also contribute to biodiversity and establishing native ecosystems. New Zealand high-country is one of the world’s most unique landscapes, wherein farming and agriculture are vital contributors to the New Zealand economy. If farm owners are not prepared for a widespread fire, the results could be devastating, damaging animals, property and land, hence having drastic economic effects.

Cleardale is a good representative of New Zealand high-country farms and there seems to be great scope in enhancing biodiversity on the farm. There are also unique opportunities for applied research regarding fire management and native biodiversity restoration at Cleardale. Ecological values of a high-country landscape are expected to decline in the future due to land degradation (Brower et al. 2020). Hence, it is vital that high-country farm owners such as Ben Todhunter, consider looking into re-designing their lands and active management and monitoring of any invasive or problematic species that may threaten farm safety, as well as high-country biodiversity.

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3.8 Appendix 1

Interview questions:

- What is the biodiversity status of this farm/Rakaia?
- What are your current fire management strategies?
- Have you ever considered using green firebreaks before?
- What is the climate usually like around Cleardale?
- How are the winds like? Are they dry?
- What are you using for grazing at the moment?
- Any cultural and biodiversity assets?
- Is there much of a human population around?
- Have there been any catastrophic fires around Cleardale or Rakaia in the past?

3.9 Appendix 2

List of low flammability native New Zealand plant species, which may be included in green firebreaks. Flammability information retrieved from Cui et al. (2020). Common names retrieved from New Zealand Plant Conservation Network (https://www.nzpcn.org.nz/flora/)

Common Name	Scientific Name
Slender New Zealand Daisy	*Lagenophora cuneata*
No common name yet, but belongs to Asteraceae family	*Brachyscome longiscapa*
Creeping/Slender Everlasting Daisy	*Helichrysum filicaule*
No common name yet, but belongs to Asteraceae family	*Leptinella pectinata*
New Zealand harebell	*Wahlenbergia albomarginata*
No common name yet, but belongs to Araliaceae family	*Hydrocotyle novae-zelandiae*
Aromatic aniseed	*Anisotome aromatica*
Taupata/Looking glass plant/Mirror plant	*Coprosma repens*
Karamū	*Coprosma robusta*
Karaka	*Corynocarpus laevigatus*
Kohekohe	*Dysoxylum spectabile*
Hangehange	*Geniostoma ligustrifolium*
Five-Finger	*Pseudopanax arboreus*
Poroporo/bullibulli	*Solanum laciniatum*
No common name yet, but belongs to Geraniaceae family	*Geranium microphyllum*
Mountain violet/white violet	*Viola cunninghamii*
Red woodrush	*Luzula rufa*
Kawakawa/Pepper tree	*Piper excelsum*
Alpine clubmoss/Mountain clubmoss	*Lycopodium fastigiatum*
Large-flowered mat daisy	*Raoulia grandiflora*
Kowhai	*Sophora microphylla*
Manatu/Ribbonwood/Lowland ribbonwood	*Plagianthus regius*
Horoeka/Lancewood	*Pseudopanax crassifolius*
Geum/Mountain avens	*Geum leiospermum*
Willowherb	*Epilobium alsinoides*
No common name yet, but belongs to Poaceae family	*Agrostis muelleriana*
Wharariki/Mountain flax	*Phormium cookianum*
Harakeke/Flax	*Phormium tenax*
Red mapou/Red matipo/Red maple	*Myrsine australis*
Pekapeka/Common mountain daisy	*Celmisia gracilenta*
Putaputaweta/Marbleleaf	*Carpodetus serratus*
Drapetes dieffenbachia Hook	*Kelleria dieffenbachii*
Bristle tussock	*Rytidosperma setifolium*
Sedge	*Carex wakatipu*
Short-flowered cranesbill	*Geranium sessiliflorum*
Little hard fern/Alpine hard fern	*Blechnum penna-marina*
Creeping eyebright	*Euphrasia dyeri*

Chapter 4: **Browsing/ grazing damage on exotic and native plant species by pest herbivores along vegetation types**

Maximillion Sterk

4.1 Introduction

In most temperate and boreal ecosystems, the abundance and distribution of medium to large size herbivorous mammals are mainly affected by humans throughout history. Due to major anthropogenic impacts on the landscape, wild herbivores have long been perceived as conflicting with livestock farming, agriculture and forestry. In contrast, the ecological understanding of the importance of herbivory for the maintenance of habitat values and biodiversity has been improved. For example, the use of livestock and wild herbivores can help to compensate and restore modified ecosystems by maintaining habitat heterogeneity.

Each ecosystem and landscape is complex and unique, which makes it difficult to make general predictions on how and to which extent wild herbivores or livestock affect the local vegetation. As herbivory can have direct or indirect effects on individual plants, it can impact the whole diversity and mass of vegetation (Bernes et al., 2016).

4.1.1 Impacts on vegetation by pest species

In New Zealand's high country, alpine and subalpine vegetation are the dominant vegetation types, consisting of indigenous forests, shrub and grasslands. During the past decades, alpine and subalpine communities have been modified and have been browsed and grazed by domestic and feral sheep, cattle, horses and goats, as well as by wild hares, rabbits, deer, chamois, tahr, wallabies, pigs and possums.

Feeding pressure by herbivorous mammals has significant impacts on the survival, growth and reproduction of individual plants. Furthermore, it can depress diversity, modify relationships of plant species and change structures in plant communities (Wong & Hickling, 1999).

To date, the Department of Conservation has noted mammal herbivory as a critical threat for 18 of the 22 threatened plant species in New Zealand (Parkes & Murphy, 2003).

If domestic, feral and wild herbivores can pose a threat to indigenous flora. Especially in fragile ecosystems like New Zealand's mountainous terrain, these areas deserve increased attention for conservation.

4.1.2 Study task

During a three-day field trip to Cleardale Station and Taniwha Farm in March 2020, I assessed the impact of browsing and grazing damage by wild herbivores on the diversity of plants. Hereby I controlled, counted and identified bite marks on vegetation and other damage to habitat structures. Furthermore, I compared affected native and exotic plant species along the different vegetation types. Afterwards, collected data was ranked in a risk assessment.

4.1.3 Importance of the study

This research aims to assist conservation managers and landowners like Ben Todhunter to improve productivity and performance of ecosystems and to give a wider understanding of how biodiversity and other ecological values vary with grazing and browsing pressures. It is an important aspect for managing pastures in agriculture and a critical tool for biodiversity conservation (Bernes et al., 2016).

4.2 Methods

4.2.1 Preparation

Farm owner Ben Todhunter kindly invited us to his house and gave us a general introduction to his farm and its management. He expressed some of his research interests and opportunities, as well as problems and difficulties of the daily farm work. We then went on exploring the farm to get an overview about its structure, borders, vegetation types and more.

4.2.2 On-site inspection

During the following two days (19-20. March 2020), the focus of this field study was to locate different vegetation types, search for the presence of herbivorous pest mammals and to conduct 2-4 stratified-random plot surveys in each vegetation type. Therefore, the area between a power station at a little stream halfway up a gully, down towards a wide-spread terrace, was assessed. Additionally, one area of the floodplain terraces was added to the survey.

However, alternating intensive agriculture plots, pasture lands, subdued channel patterns and steeper grassland terraces with livestock were not included.

As '*vegetation types are characterized by full floristic and growth form (physiognomic) composition, which together express ecological and biogeographical relations'* (Module in Earth Systems and Environmental Sciences, 2020), I searched for variations in plant communities in the landscape and identified six different vegetation types (Table 1).

Figure 4-1 Plot design

While identifying vegetation types, I simultaneously checked for evidence of pest mammals. Accordingly, I looked for scats, pellets, hairs, footprints and other tracks at specific locations such as large solitary boulders, pathways and patches without vegetation.

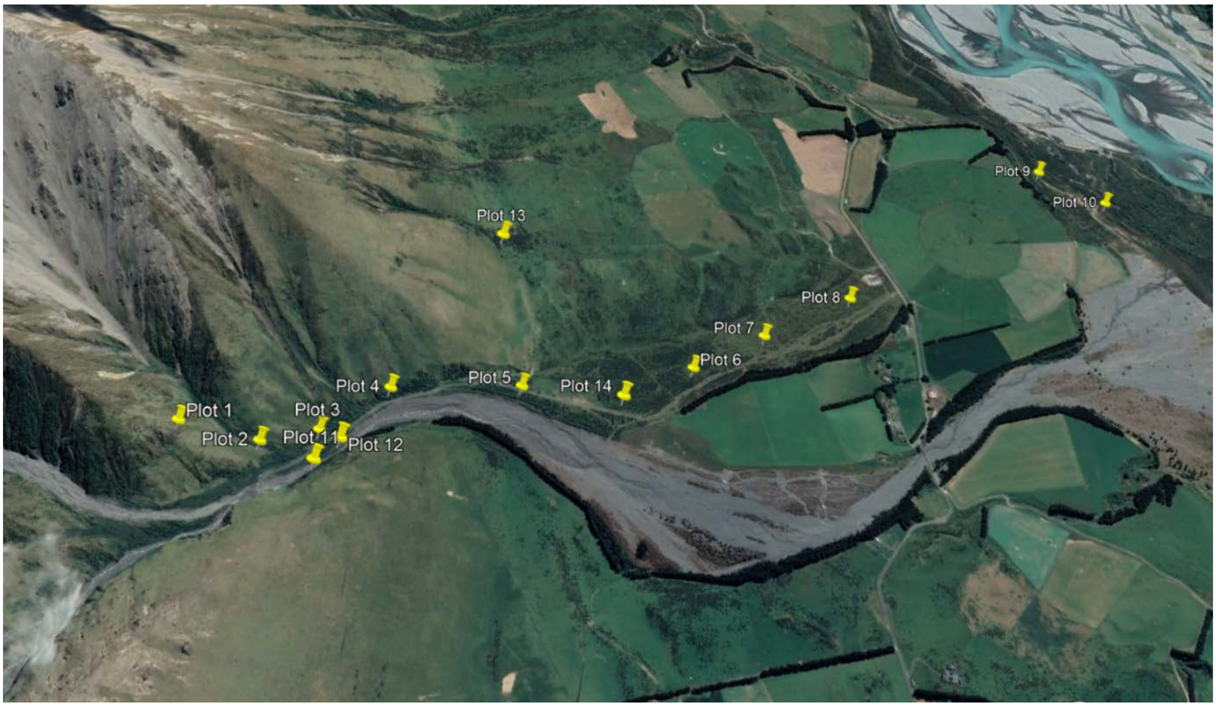

Figure 4-2: ***Location of plots. Image by Google Earth, 2020***

A stratified-random plot survey was conducted afterwards, using the previously identified vegetation types. This means that the farm was divided into the vegetation types, in which 2-4 random areas were selected. The gradient of the vegetation types depends on a road along a little stream which was used to access the upper elevation parts of the farm (Figure 2). In all vegetation types, two plots were assessed, apart from the 'mixed shrub and grasslands' (4 plots) which holds more diverse habitats (**Table 1**).

Table 4-1: ***Distribution of plot numbers along vegetation types***

Vegetation type	Number of plots
Grasslands	2
Streams	2
Farmed foothills	2
Mixed shrub and grasslands	4
Forests	2
Riverbed	2

All the 14 plots had a standardised size which was 20 m x 20 m. The plot size was measured using a measuring tape and its corners marked with bright coloured tapes.

Native and exotic vegetation were sampled with a special focus on damage by wild herbivores. Hereby, plants with bite marks were identified. Subsequently, the bite marks were counted and pictures were taken for further identification and all plots marked with GPS.

4.3 Results

4.3.1 Vegetation types

Apart from the natural flowing Rakaia River with its wide gravel-riverbed, the adjacent landscape is mainly influenced by humans. Tessellated patches of tall conifers, little forests and native bushes in between large pasture lands form the overall appearance of the landscape.

From the lower mountain slopes of the Mt. Hutt range down to the Rakaia riverbed, six different vegetation types were identified. Montane **grasslands and herbfields** with *tussocks, exotic grasses and subalpine scrub*s occur on the upper slopes (Figure 3). Little **streams** flow through the gullies and carry gravel and rocks in its riverbeds towards the terraces and Rakaia floodplain. In some areas, the banks are densely covered with *tutu, water mint, Coprosma, matagouri, weeds and herbs* (Figure 4).

The lower mountain slopes are extensively **farmed foothills** with **mixed shrub and grasslands** (with *matagouri, mingimingi, bracken, red and tussocks*) as well as some delimited **forests** (*exotic poplar forest and mixed native forest with kanuka, beech, broadleaved scrubs*) (Figure 5-8). The farmed foothills are characterised by strong overgrazing from livestock, while mixed shrub and grasslands show more native shrubs, i.e. matagouri.

On the other hand, dense exotic *gorse, weeds, cabbage tree and exotic broom* occur along the Rakaia **floodplain** (Figure 9).

Figure 4-3: ***Grasslands***

Figure 4-4: ***Stream***


Figure 4-5: Farmed foothills


Figure 4-6 Mixed shrub and grasslands


Figure 4-7: Mixed forest


Figure 4-8: Poplar Forest


Figure 4-9: Floodplain

4.3.2 Confirmed presence of herbivorous pest mammals

During the identification of vegetation types, the presence of different pest species was confirmed (Figure 10-12). The area is populated by herbivores (brown hare, *Lepus europaeus*) and omnivores (possum, *Trichosurus vulpecula*) which can cause damage to native fauna and flora. Additionally, the evidence of deer was found, although we were not able to identify the actual species. Moreover, several predator traps were found along the Rakaia River, which led to the assumption that predators like mustelids, hedgehogs and rats are also present in this area.

Although the abundance of pest species might differ throughout the area, population numbers of hare and possum seem to be much higher than of deer. In addition to direct observations of hare, numerous hare pellets and scats of possums were found across the farm.

The presence of deer was only confirmed in the upper elevation zones but tracks of hares and possums were found in all vegetation types. It seems that deer avoid walking further down towards the Rakaia riverbed. This could be attributed to their shy behaviour, associated with the increased human activity in this area.

Figure 4-10: Possum scat

Figure 4-11: Hare pallets

Figure 4-12: Deer pellets

4.3.3 Browsing and grazing damage on identified plant species

Through surveying plant communities with vegetation plots, different species showed varying degrees of damage (Table 2). Across all vegetation types, tutu (*Coriaria arborea*) showed most damage by wild herbivores. They were primarily found up the little stream and in the adjacent mixed shrub and grasslands. In both areas many individuals were heavily damaged (up to 80% of original habitat). Likewise, exotic water-mint (*Mentha aquatica*) was pitted strongly near another little stream situated within the farmed foothills. Native broom (*Carmichaelia australis*), which mainly occurs by the Rakaia riverbed, possessed numerous bite marks as well. Hereby, one individual in the grasslands was browsed completely and showed distinctive bite marks from herbivorous mammals.

Figure 4-13: Damaged tutu (Coriaria arborea)

In contrary to young and fresh shoots of bracken fern (*Pteridium esculentum*) which were favoured by herbivores, older and dry parts did not show any damage. Because bracken ferns were only found on the farmed foothills, it is more likely that livestock was feeding on them.

Interestingly, some matagouri (*Discaria toumatou*) in the mixed shrub and grasslands which have been pitted near ground level did not show any damage on the upper parts. This could be evidence of mice and/or hare browsing. Broadleaf (*Griselinia littoralis*), poataniwha (*Melicope simplex*), needle-leaved mountain coprosma (*Coprosma rugosa*) and exotic poplar (*Populus* sp.) had no significant damage by herbivores, although few parts possessed little bite marks. Besides water-mint and poplar, which were imported by humans in the past, most identified species are native to New Zealand.

Figure 4-14: Damaged broom (Carmichaelia australis) with clear cuts and chewed parts

Table 4-2: Identified native and exotic species damaged by herbivores

Species	**Origin**	**Damage**
Coriaria arborea (tutu)	Native	Strong
Mentha aquatica (water-mint)	Exotic	Strong
Carmichaelia australis (broom)	Native	Strong-medium
Pteridium esculentum (bracken fern)	Native	Medium
Discaria toumatou (matagouri)	Native	Little
Griselinia littoralis (broadleaf, Kapuka)	Native	Little
Melicope simplex (poataniwha)	Native	Little
Coprosma rugosa (needle-leaved mountain coprosma)	Native	Little
Populus sp. (poplar)	Exotic	Little

4.4 Discussion

4.4.1 Identifying the main wild herbivore

The average height range of bite marks on tutu, water-mint, matagouri and broom lied between 0-80 cm from ground level. Taking into consideration the habitat structure of the bushy areas, including hiding possibilities against predators and shelter, I assume that hare is the main herbivore. The large numbers of hare in these areas would fit the hypothesis (Puig & Videla & Mónica et al., 2007).

On the contrary, we were not able to identify and explain impacts by deer. This happened due to deer tracks being mistaken for tracks of sheep.

Difficulties arose when trying to identify unclear bite marks. Taking this into consideration, I suggest that insects (which were not assessed) might have significant feeding impacts as well.

4.4.2 Evaluating risk of damaged vegetation types

After identifying individual plant species exposing bite marks from herbivores, the whole plant community and vegetation type were surveyed. Therefore, the amount and the degree of damaged species of a specific vegetation type were established as the main criteria for assessing the risk of herbivorous feeding pressure.

Accordingly, mixed shrub and grasslands include large patches of the most heavily damaged plant species, i.e. tutu. It is also the most diverse vegetation type regarding the distribution of habitats with high densities of matagouri. These bushy habitats provide shelter for animals like hare, possum and deer. Because of its favourable habitat structure and suitable food plants for herbivores, it is identified with a high risk for browsing and grazing damage.

Natural flowing streams are very sensible ecosystems reacting to minor changes in environmental conditions (Young & Townsend & Mathaei, 2004). Local differences of favourable conditions reflect the species diversity, distribution and composition as well. With large patches of tutu and some parts with water mint showing major damage, it is as an additional pressure on the plant species survival as well as for the diversity of this vegetation type.

Farmed foothills were already identified with strong overgrazing by domestic mammals. However, some additional browsing marks on plants lead to the assumption that wild herbivores are using this vegetation type as a habitat, similar to the mixed shrub and grasslands.

In the Rakaia floodplain, in comparison to the native broom which had some bite marks, the very dense gorse thicket did not show any damage. Because of a confirmed high abundance of hare and its focus on native broom as an edible plant, it is possible that this high browsing pressure will have negative impacts on the survival of native species on the long term. Through this, gorse might benefit as well by overgrowing weak competitors.

The two forest types and grasslands had no significant damage by herbivores, which means that these vegetation types don’t have to be the focus of further pest management actions.

4.4.3 Effects and management of herbivores

Herbivory is an important aspect of Ben Todhunter's farm to manage productivity and performance. The riverbed with its floodplains, the lower mountain slopes and streams show the highest values for conservation because they hold comparatively more native and diverse vegetation. However, the same areas are at risk of overgrazing by herbivorous pest mammals. Especially the large matagouri and gorse thickets provide suitable habitats for herbivores with enough hiding places. It is assumed that hare, possum and possibly deer occurring in these areas at the same time have significant impacts on the local vegetation due to their feeding behaviour. Thus, their presence might have negative impacts on native birds and reptiles as well because they compete for the same food sources.

For the more natural areas, increased pest control can help to contain population numbers and their damage. In practice, traps and bait stations can be used to target stoats, rats, possums and hedgehogs while deer and hares usually have to be hunted (DOC[1]).

In contrast, the flats and terraces are highly impacted by anthropogenic factors and completely transformed into an intensive, profit-oriented farming zone with many exotic species. For the pasturelands, no significant risks were identified, and no intensive management is needed.

4.4.4 Further restoration and potential of the farm

Restoration helps the recovery of various ecosystem features and processes. Patches with native vegetation increase the overall species diversity and composition. Furthermore, they hold possible habitats for local fauna which can be used for livestock as well, as a higher abundance of shrubs and trees provides more shelter (Simberloff, 2019). Cleardale Station's main aim should be to enlarge and connect more natural areas without losing much pastureland. This can be achieved by planting native forests and bushlands as a biotope network from the mountain range down to the Rakaia River, as well as creating more reserves.

Figure 4-15: View from subalpine grasslands down the little stream feeding the Rakaia River

[1] https://www.doc.govt.nz/nature/pests-and-threats/methods-of-control/

Browsing and grazing can have negative impacts on restoration, thus herbivory needs to be actively managed. For example, fencing off seedlings and greasing young trees with a special mixture can repel herbivores, while weeds can be controlled by hand or with herbicides (DOC, 2009).

In contrast, controlled feeding pressure can be an option to fight the dispersion of exotic weeds (grasslands) and to maintain habitat heterogeneity (forests). Nevertheless, it is difficult to address specific plant species with herbivores.

Shrublands can sustain low numbers of herbivores. As shown in a previous study, grazing by deer reduced the development of the bush stand, although bush increased by 50%. (Johnson & Fitzhugh, 1990.) Taking this into account, controlled numbers of wild herbivores can help managing the farm in a natural way. Additionally, this can be combined with tourism and recreational game hunting, as a new potential income.

4.5 Future possible studies

Conducting a camera trap survey at specific locations like animal paths and water points can confirm the occurrence and abundance of wild herbivores. This would give more details about their daily migrations (e.g. from the mountains down to the valleys) and feeding areas (Latham & Fitzgerald & Warburton, 2017).

While exclusion plots can be used to compare browsing and grazing impacts directly on the survival of plant species, as well as species composition along different vegetation types. However, to identify differences in damage between fenced off areas and identified browsing/grazing areas can take a long time. This could be done in long-time study (Husheer & Coomes & Robertson, 2003).

4.6 Conclusion

During a three-day field study at Cleardale Station in Canterbury, the evidence of three wild herbivores was confirmed (brown hare, possum and deer). Through a vegetation plot survey, I found significant impacts of browsing and grazing damage by wild herbivores. By controlling, counting and identifying bite marks on individual plants, tutu (*Coriaria arborea*), water-mint (*Mentha aquatica*) and broom (*Carmichaelia australis*) showed the most damage. Associating the average height range of bite marks on these plant species with the habitat structure where they occur, brown hare was identified as the main herbivore.

Including the amount and the degree of damaged species in each vegetation type, mixed shrub and grasslands, natural flowing streams and the Rakaia floodplain are at the highest risk of herbivorous damage, while the grasslands and forests did not show any significant damage.

As a recommendation, further restoration at Cleardale Station should focus on a biotope network from the mountain range down to the Rakaia River including the management of wild herbivores.

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Chapter 5: **The Butterfly and Moth Fauna of Cleardale Station, Canterbury**

Jonas Wobker

5.1 Background

Worldwide 160,000 species of Lepidoptera (butterflies and moths) are known and many more are lacking description (Mitter et al. 2017). They inhabit a wide a range of terrestrial habitats on all continents except Antarctica. Lepidoptera are known to be good bioindicators reflecting environmental changes (Gerlach et al. 2013). Therefore, studying Leipdoptera has a huge potential from a conservation biological perspective to assess the effects of land-use and the efficiency of conservation measures. Moreover, they fulfil important ecosystem services like pollination (Lebuhn et al. 2013). Globally, insects, like butterflies and moths, are known to decline in a variety of places and habitats (Lebuhn et al. 2013; Sánchez-Bayo and Wyckhuys 2019).

New Zealand's butterfly and moth fauna includes about 2.000 described species (Patrick 2004). As it is typical for islands a disharmonic representation of the world's major families can be found in New Zealand. This means that many Lepidoptera families commonly found globally are underrepresented in New Zealand, whereas other families are overrepresented (Patrick 2004). Furthermore, the Lepidoptera fauna of New Zealand is characterised by a very high level of endemism with 94% of all species being endemic. However, the information about the conservation status of New Zealand's butterfly and moth species are sparse, only for 11% of all species a conservation status, evaluating the population development and threats of the species, is assessed (Hoare et al. 2017).

Many of New Zealand's Lepidoptera species, especially moths, are associated with tussock grassland in the low- and the high-country (McGuinness 2001; Patrick 2004). The tussock moth-fauna is so unique in terms of endemism, species richness and special features that it is regarded as being of global importance (Patrick 2004). This tussock-moth fauna is mostly restricted to the South Island and can be found from coastal up to high-mountain areas. Despite the lack of information about the population trends, there are strong hints that the populations of many common and rare species are declining (White 1991).

Threats impacting native Lepidoptera include habitat destruction and fragmentation, overgrazing and intensification, the loss of native food plants and the predation by exotic mammals and birds.

To establish effective conservation measures and to understand the ecological needs of species more research is needed. To get a little insight in Lepidoptera of an exemplary New Zealand farming station, this project investigated the butterfly and moth-fauna at Cleardale Station.

5.2 Aim

The main aim of this project was to create an inventory of butterfly and moth species, which can be found at Cleardale Station. A special focus was laid on the different habitats of Cleardale Station to assess the differences in the butterfly- and moth-communities between those habitats. This is especially interesting since Cleardale Station offers a wide range of habitats at different elevation levels. The three habitats investigated in this project were tussock grasslands at higher elevations, the edge of a native forest and scrubland mainly consisting of the native matagouri scrub *Discaria toumatou*. The collected information helps to evaluate the conservation value of the different habitats and derive implications for farm management and conservation measures.

5.3 Methods

Sampling of butterflies and moths was conducted on 19 and 20 March 2020. Twelve yellow-pan traps were placed in three different habitats: four in tussock grassland at higher elevations, two at the edge of the edge of a native forest and six in the matagouri shrubland (Fig. 1 and Fig. 2). Yellow pan-traps were filled with a water soap mixture. By their bright colour they are imitating flowers and therefore attract all kinds of pollinators like butterflies and moths (Saunders and Luck 2013). The traps were placed on the 19 March and collected on the next day.

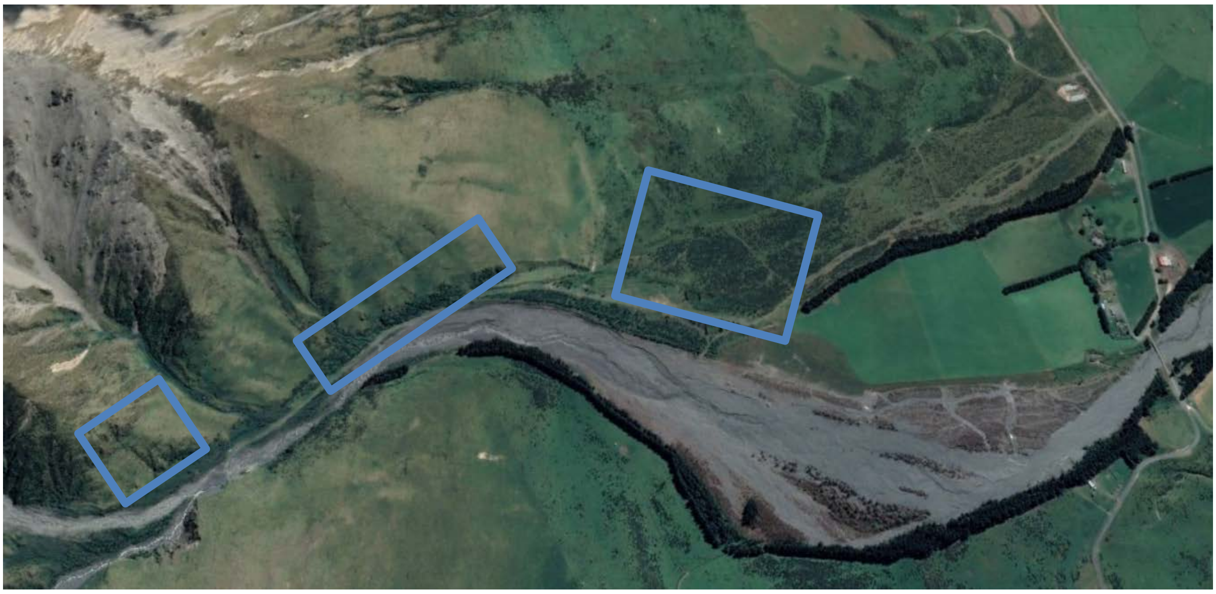

Figure 5-1: ***Map indicating the sampled areas.***
From left to right: Tussock grassland (four pan traps), edge of native forest (two pan traps and one (two) UV light traps) and matagouri shrubland (six pan traps). Map: Google Earth

Moreover, butterflies and moths were caught with a net inside and outside of the three habitat types.

In addition to the pan traps one blue UV light traps and a conventional LED light trap were used in the night of the 19 and 20 March. The traps were located at the forest edge in proximity to the two yellow pan traps. However, there was a malfunction in the LED trap, therefore effectively only one UV-light trap worked. These traps were used to sample the moth fauna of the area. For the analyses of the habitats the specimens from the light trap were excluded and put in an own category. In addition, butterflies and moths were caught with a net.

All specimens were sampled and photographed. All pictures were uploaded to the citizen science website iNaturalistNZ (www.inaturalist.org) for identification.

Figure 5-2: ***Yellow pan traps in two different habitats***

5.4 Results

5.4.1 General observations

On the first day of sampling the weather was sunny without precipitation, thus the flight activity of butterflies and moths was high. On the second day the weather was foggy and rainy, therefore a lower flight activity was observed. This could have also impacted the catching success with the pan traps, which was overall low.

5.4.2 Butterflies

Four butterfly species were found at Cleardale Station of which were two endemic and one exotic (Tab.1). The endemic species were two species of the Copper butterfly group, the Canterbury alpine boulder copper *Lycaena tama* (Fig. 3) and an undescribed species from the Common copper butterfly group *Lycaena* sp. (Fig. 4). Moreover, the native Yellow admiral *Vanessa itea* and the exotic White butterfly *Pieris rapae* were present at Cleardale Station.

Table 5-1: ***Butterfly species recorded at Cleardale Station***

Scientific name	English name	Status
Lycaena tama	Canterbury alpine boulder copper	Endemic
Lyceana sp.	Common copper group	Endemic
Vanessa itea	Yellow admiral	Native
Pieris rapae	White butterfly	Exotic

Figure 5-3: ***Lycaena tama (male)***
Source: Mike Bowie

Figure 5-4: ***Lycaena* sp. *(male)***
Source: Jonas Wobker

5.4.3 Moths

Eleven moth species were recorded at the study site. Seven of these species were endemic and three were exotic (Tab. 2). The most abundant species were the day-flying *Paranotoreas brephosata* (Fig.5) and the Clematis triangle *Deana hybreasalis* (Fig.6).

Table 5-2: ***Moth species recorded at Cleardale Station***

Scientific name	English name	Status
Scopula rubraria	Plantain moth	Native
Deana hybreasalis	Clematis triangle	Endemic
Austrocidaria sp.	-	Endemic
Ichneutica propria	-	Endemic
Monopis crocicapitella	Bird nest moth	Exotic
Xanthorhoe semifissata	Barred pink carpet moth	Endemic
Orocrambus ramosellus	-	Endemic
Agrotis ipsilon	Dark sword-grass	Exotic
Plutella xylostella	Cabbage moth	Exotic
Paranotoreas brephosata	-	Endemic
Helastia corcularia	-	Endemic

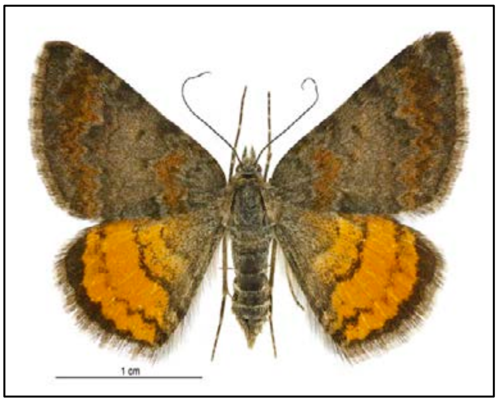

Figure 5-5: ***Paranotoreas brephosata***
Source: www.landcareresearch.co.nz

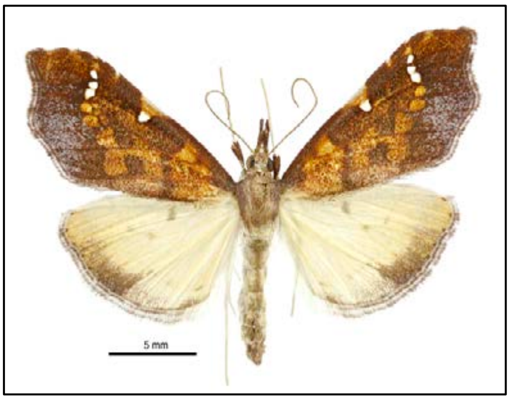

Figure 5-6: ***Deana hybreasalis***
Source: www.landcareresearch.co.nz

5.4.4 Habitats

In all three habitats a similar number of Lepidoptera species were found, with six species in each of the habitats (Tab. 3 and Fig. 6). With the UV-light trap close to the forest seven species were caught.

Table 5-3: Number of species recorded in different habitats

Habitat	Number of Species
Grassland	6
Forest edge	6
Matagouri shrubland	6
UV-light trap	7

Figure 5-7: Pictures of the three sampled habitats (Grasslands, forest edge, matagouri shrubland).

5.5 Discussion

5.5.1 Species

Overall, four species of butterflies and eleven species of moths were found at Cleardale Station. The majority of the species (60%) were endemic reflecting the high percentage of endemics in New Zealand. However, compared to the overall proportion of endemic species in New Zealand (94%), a proportion of 60% is comparatively low (McGuinness 2001).

In this context it must be mentioned that the results are only showing a fraction of the actual Lepidoptera fauna at Cleardale Station, considering the small sampling time. Yet, even in this limited time species of conservational value were found representing a wide range of taxonomic groups and habitats.

5.5.2 Copper butterflies

Two species of interest found at Cleardale Station are the two Copper butterflies. The taxonomy of the group of Copper butterflies in New Zealand is currently under debate. Traditionally, four species of Copper butterflies were distinguished in New Zealand, the Common copper *Lycaena salustius*, the Boulder Copper *Lycaena boldenarum*, the Glade copper *Lycaena feredayi* and Rauparaha's copper *Lycaena rauparaha* (Arter-Williamson 2016). After taxonomic changes, at least seven species will be recognised, however this still leaves many potential species undescribed and it is likely that further investigations would reveal more Copper butterfly species in New Zealand (Patrick 2018).

The Canterbury alpine boulder copper, which was commonly found at the site, was just recently split from the Boulder Copper. It has a very small distribution range in Canterbury and the Mackenzie-basin (Fig. 8). Information about the population size and the ecology of this species are sparse. The other Copper butterfly found at the site is an undescribed species from the Common Copper group. It can be assumed that this species has also a very limited distribution.

Taking into consideration that both species are until now comparatively poorly studied and have a limited range the observations at Cleardale Station were quite remarkable. The site holds the potential to assess more information about these species in the future.

Figure 5-8: Distribution of Canterbury alpine boulder copper Lycaena tama assessed by iNaturalistNZ (iNaturalist 2020)

5.5.3 Pollination

Pollination is an extremely important ecosystem service with a high ecological as well as economical value (Kasina et al. 2009). Especially in farming systems pollinators are essential since they act as crop pollinators (Howlett et al. 2009).

Globally, butterflies and moths play an important role as pollinators (Lebuhn et al. 2013; Mitter et al. 2017). However, the role of Lepidoptera in pollinator systems in New Zealand is poorly studied (Buxton et al. 2018). Since Lepidoptera are regularly visiting native plants it is likely that they play a role in such systems and are therefore valuable in context of ecosystem services. Yet, also other invertebrates were recorded, which are potentially acting as pollinators, like the exotic Buff-tailed Bumblebee *Bombus terrestris*, the Common Drone Fly *Eristalis tenax* and a native Sweat bee species *Lasioglossum* sp. It seems likely that all these species are contributing to the pollination in this ecosystem. Although usually native invertebrate species are most important for the pollination of native plant species, exotic invertebrate species can also act as pollinators for native plants (Mark et al. 2013). Similarly, native invertebrates can also pollinate not just native plants but also exotic weeds. However, native pollinators are extremely important for native ecosystems (Mark et al. 2013).

5.5.4 Habitats and footplants

In every sampled habitat the same number of species were recorded during this project. This shows that every of these habitats is valuable and holds a special Lepidoptera fauna. Generally, Cleardale Station has a heterogeneous landscape and besides the three sampled habitats there are other potentially valuable habitats like wetlands or the riverbed.

One of the key requirements of a butterfly or a moth habitat is the presence of food plants. This includes flowering plants as nectar source for the adult life-stage but also food plants for the larval phase. Mostly, butterfly and moth species are more specialised on the larval food plant. It is relatively common that a certain butterfly or moth species is associated with only one species or genus of plants. The *Lepidoptera* species found at Cleardale Station are associate with a variety of food plants reflecting the different habitats of the station (Tab. 4).

For the two Copper butterfly species plant species from the genus *Muehlenbeckia* are essential. Five species of this genus are native to New Zealand (Lange et al. 2017). They are small shrubs growing between rocks and boulders, at Cleardale Station they are strongly associated with the riverbed. *Deana hybreasalis* is feeding on *Clematis afoliata* a native shrub of shrublands and forest edges. *Pieris rapae* and *Plutella xylostella* feed on plants from the *Brassicaceae* family, which also includes lots of vegetables like broccoli, cabbage as well as rapeseed. The native moth *Scopula rubraria* feeds on plantain, which can be an important plant in pastures. It is even reported that this species becomes a pest species on farms when it occurs in bigger numbers (Gerard et al. 2018). *Orocrambus ramosellus* is a typical tussock moth species and feeds on tussock grasses.

Usually, native butterfly and moth species rely on native plant species as their food plants. However, sometimes a native food species can be replaced by an exotic one, as it can be seen in *Xanthorhoe semifissata,* which can feed on the native bittercress (*Cardamine debilis*) but also on exotic watercress (*Nasturtium officinale*).

Tab. 4 Food plants of selected Lepidoptera species recorded at Cleardale Station

Lepidoptera species	**Food plant**
Lycaena tama	*Muehlenbeckia axillaris*.
Lyceana sp.	*Muehlenbeckia* sp.
Vanessa itea	several species, e.g nettles *Urtica* sp.
Pieris rapae	*Brassicaceae*
Scopula rubraria	Plantain *Plantago* sp.
Deana hybreasalis	*Clematis afoliata*
Xanthorhoe semifissata	*Nasturtium officinale* and *Cardamine debilis*
Orocrambus ramosellus	Tussock grasses
Agrotis ipsilon	Several grass and weed species
Plutella xylostella	Brassicaceae

With the help of the sampling results from this project and the information about the food plants of the species, the key Lepidoptera habitats at Cleardale Station can be characterized:

Tussock grasslands: Tussock grasslands represent the habitat for New Zealands unique tussock moth fauna. Moreover, it is possible that the tussock butterfly *Argyrophenga antipodum* can be found in the area, although it was not found in this project.

Native forests and shrublands: Native forests and shrublands provide important habitats and native food plants and are therefore vital for a wide range of butterfly and moth species.

Riverbed: The riverbed provides habitat but also food plants like *Muehlenbeckia* sp., which is essential for the Copper butterflies.

Roadside: Many flowering plants, which are a nectar source for adult butterflies and moths, are growing on the side of the road.

Wetlands: Although not sampled in this project, it can be assumed that the wetlands hold a variety of Lepidoptera species specialized in this habitat.

5.5.5 Implications for conservation at Cleardale Station

This project gave a little insight in the rich Lepidoptera fauna at Cleardale Station. From a conservational point of view the important question is how to maintain and enhance this biodiversity. The main key is the provisioning of suitable habitat. As already mentioned, Cleardale Station holds a variety of valuable habitat patches for Lepidoptera. These heterogeneous landscape structure should be protected and maintained.

The key element of these habitats are the food plants of the species. For adult butterflies and moths the promotion of flowering plants is essential. For the caterpillars the species-specific food plants are vital. Generally, it should be aimed for a high diversity of native plants, which supports a high invertebrate diversity (Patrick 2004). A study from another farming system in New Zealand (vineyards) showed that remnants of native vegetation are especially important for butterfly diversity (Gillespie and Wratten 2012). Thus, it should be paid a special attention to these remnants at Cleardale Station, accompanied by restoration patches, where native plants should be reintroduced. It always should be kept in mind that some of the moth species are quite immobile, which leads to a fast fragmentation of the population (Patrick 2004). Therefore, it is crucial to connect habitat patches by corridors and steppingstone habitats (Meurk and Hall 2006).

Moreover, predator pest species should be controlled and eradicated if possible, since they are preying on invertebrates and are a threat to native invertebrate populations (Patrick 2004).

In the context of farming the effect of grazing on Lepidoptera fauna is extremely interesting. Although overgrazing and the following degradation of grasslands is surely harmful for butterfly- and moth- communities, it is reported that New Zealand' tussock moths are quite resilient and can deal with certain levels of grazing (Patrick 2004; Jerrentrup et al. 2014). Thus, semi-natural grazed areas can still support a rich Lepidoptera biodiversity as long as grazing is not too intensive (Patrick 2004). Grazing of exotic herbivore species might be even a possibility to reduce exotic weed species (White 1991).

All these ideas must be of course in line with economical needs of farming. It should be aimed for the incorporation of conservation measures into farming measures. A possible example could be the planting of clover as nitrogen-fixing plant, which also provides nectar for butterflies and moths and enhances the ecosystem service of pollination. Moreover, "butterfly-friendly farming" could be used as a marketing claim to promote the products of Cleardale Station.

5.5.6 Future research

Cleardale Station holds enormous potential for future research. A further inventory of the Lepidoptera fauna would be extremely useful as a baseline dataset for upcoming projects. Therefore, sampling periods should be as long as possible and at different seasons of the year. Moreover, the site gives the opportunity to learn more about poorly studied species like the Canterbury alpine boulder copper.

Additionally, it would be useful to further assess the key habitat fragments of the area and to evaluate the effectiveness of restoration plots in terms of butterfly and moth conservation. Overall stands the question how to combine farming and effective conservation measures. To work on this question in the future is a crucial part of butterfly and moth conservation in farming systems of New Zealand.

5.6 Conclusion

Even in the short time of this project it was shown that Cleardale Station with its heterogenous landscape and different elevation levels has a huge potential to support a rich butterfly and moth fauna with its many endemic and unique species. This biodiversity should be maintained and enhanced by conservation measures, which are incorporated in the farming processes and are adapted to the economic needs of farming. To design effective measures further research in the future would be extremely useful.

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Chapter 6: **Tracking tunnel analysis on Cleardale Station – Threatened Endemic Birds' Predators**

Aline Freire de Miranda Cavalcante

Abstract

Threatened Endemic Birds' Predators

Rakaia's riverbed is a breeding site for two New Zealand endemic threatened species, the Wrybill (*Anarhynchus frontalis*) and the Black-fronted tern (*Chlidonias albostriatus*). Predation by invasive mammals is one of the main threats to those species survival. The present study conducted a preliminary survey of the mentioned birds predators in Cleardale Station area, a farm located at Rakaia River's area. The Department of Conservation (DOC) runs a Predator Control Project in a broader area which encompasses the study area. We placed three lines with ten tracking tunnels each. The lines were 50 meters apart from each other, covering nearly half of a kilometre. Tracking tunnels were collected after 24 hours. Tracks from skink, mice and hedgehog were identified. Amongst DOC's most captured species were hedgehogs as well. There are some relevant differences between DOC's work and the present survey, the main ones being the size of the area, the duration and the traps' location. On the one hand DOC's project is implemented in a much broader area than the one considered to conduct this survey, moreover it runs for several months in a year and it was the second year of the project at Rakaia River. On the other hand we placed the traps more vastly among micro ecosystems. Despite the big difference in area size and duration we were able to identify DOC's most registered predator. Therefore, we intend to compare our results with DOC's project's expecting to contribute to it with useful and valuable information for the conservation of Wrybill and the Black-fronted tern.

Keywords: Wrybill, Black-fronted tern, *Anarhynchus frontalis, Chlidonias albostriatus*, threatened, endemic, birds, predators, hedgehog, Rakaia River, riverbed, breeding, Department of Conservation .

6.1 Introduction

Cleardale Station is a farm located at the south side of Rakaia River, approximately 10 km in land from Rakaia Gorge. Rakaia's riverbed is a breeding site for Wrybill (*Anarhynchus frontalis*) and Black-fronted tern (*Chlidonias albostriatus*), two New Zealand endemic threatened species (DOC, 2020a; DOC, 2020b). According to New Zealand's Department of Conservation (DOC, 2020a) Wrybill current conservation status is nationally vulnerable while Black-fronted tern is nationally endangered (DOC, 2020b). Classifications are based on the New Zealand Threat Classification System and mean Wrybill faces extinction risk in medium term and Black-fronted tern faces a high extinction risk in short term (DOC, 2020c). Amongst the main threats to this species survival is predation (DOC, 2020a; DOC, 2020b). Its chicks are food for other birds as well as for mammals, against which the species have no defence strategies once they evolved without this type of threat (DOC, 2012). This study aims to survey Wrybill and Black-fronted tern predators in the area and to compare the results with DOC's programme's expecting to contribute to it with useful and valuable information for the conservation of those species.

The area of study is part of New Zealand's high country landscape.

6.2 Methodology

Three lines of tracking tunnels were placed in the area. One was established up the mountains, one was nearby Rakaia River and the other, in between. Each line had 10 tracking tunnels 10 meters apart and were spaced approximately 50 meters from each other, thereby covering nearly half a kilometer. For logistic reasons the line closest to Rakaia River was placed in a parallel direction of the river while the two other lines were placed perpendicularly to it. All tracking tunnels were bated with peanut butter and were collected the day after settlement.

Figure 6-1: Tracking tunnels' map

Table 6-1: Line 1 tracking tunnels coordinates (LAT - latitude; LONG - longitude), elevation and placing time

LINE 1				
TRACKING TUNNEL	**LAT**	**LONG**	**ELEVATION**	**TIME**
TT1	-43.454584	171.559636	749.683411	11:07:03Z
TT2	-43.45429701	171.560126	736.462463	11:14:38Z
TT3	-43.45406801	171.560686	727.680664	11:23:28Z
TT4	-43.45381698	171.561193	717.765686	11:26:59Z
TT5	-43.45346301	171.561689	704.064819	11:51:44Z
TT6	-43.453102	171.56217	692.968262	11:55:37Z
TT7	-43.452743	171.562547	682.435974	11:59:38Z
TT8	-43.45246699	171.563114	675.023071	12:06:15Z
TT9	-43.45213397	171.563563	663.766846	12:43:49Z
TT10	-43.45172896	171.563897	661.179504	12:50:05Z

Table 6-2: Line 2 tracking tunnels coordinates (LAT - latitude; LONG - longitude), elevation and placing time

LINE 2				
TRACKING TUNNEL	**LAT**	**LONG**	**ELEVATION**	**TIME**
TT11	-43.43984996	171.594067	316.510651	14:45:47Z
TT12	-43.44021298	171.594448	316.841675	14:48:06Z
TT13	-43.440519	171.594897	317.762512	14:50:25Z
TT14	-43.44085696	171.595373	317.734406	14:52:15Z
TT15	-43.44113298	171.595868	316.929016	14:53:55Z
TT16	-43.44136398	171.596427	316.755859	14:55:53Z
TT17	-43.44172901	171.596798	316.187164	14:58:02Z
TT18	-43.442187	171.59694	313.383606	15:00:10Z
TT19	-43.44256402	171.597267	312.777771	15:02:09Z
TT20	-43.44293199	171.597742	311.114777	15:04:00Z

Table 6-3: Line 3 tracking tunnels coordinates (LAT - latitude; LONG - longitude), elevation and placing time

LINE 3				
TRACKING TUNNEL	**LAT**	**LONG**	**ELEVATION**	**TIME**
TT21	-43.448687	171.580899	468.326904	15:17:09Z
TT22	-43.44886302	171.580325	472.593262	15:18:39Z
TT23	-43.44903301	171.579712	479.194672	15:20:57Z
TT24	-43.44927097	171.579185	484.563385	15:23:24Z
TT25	-43.44949602	171.57863	491.679016	15:26:55Z
TT26	-43.44855599	171.581552	460.468567	15:38:18Z
TT27	-43.44854501	171.582174	457.883148	15:40:07Z
TT28	-43.44829003	171.582658	455.013123	15:41:53Z
TT29	-43.44800304	171.583173	444.243195	15:43:44Z
TT30	-43.44777999	171.583704	440.668488	15:45:31Z

Figure 6-2: TT4

Figure 6-3: TT10

Figure 6-4: TT13

6.2.1 Time of the Year

The traps were placed on March 19 and collected on March 20, 2020.

6.2.2 Weather Conditions

On March 19 the temperature was approximately 23°C and the day was windy (speed unknown). On March 20 the temperature was approximately 13°C, there was no noticeable wind and there was light rain (precipitation unknown).

6.3 Results

From the 30 tracking tunnels placed, 15 did not get any tracks. One single tracking tunnel registered lizard tracks while 4 had mice tracks and 10 presented hedgehogs tracks. The results are summarized on tables 4 and 5 per line and per tracking tunnel, respectively. Tracking tunnel 21 had its card partially out.

Table 6-4: Tracking tunnel lines and general results

Line	Skink	Mice	Hedgehog	None	Total Registers
1	1	4	2	3	**7**
2	0	0	3	7	**3**
3	0	0	5	5	**5**
TOTAL	**1**	**4**	**10**	**15**	**15**

Table 6-5: Single tracking tunnels results

LINE 1		**LINE 2**		**LINE 3**	
Tracking Tunnel	**Track**	**Tracking Tunnel**	**Track**	**Tracking Tunnel**	**Track**
TT1	Skink	TT11	0	TT21	0
TT2	Mice	TT12	0	TT22	0
TT3	Mice	TT13	0	TT23	0
TT4	Hedgehog	TT14	Hedgehog	TT24	0
TT5	0	TT15	0	TT25	Hedgehog
TT6	Mice	TT16	0	TT26	Hedgehog
TT7	Hedgehog	TT17	Hedgehog	TT27	Hedgehog
TT8	0	TT18	0	TT28	Hedgehog
TT9	Mice	TT19	0	TT29	Hedgehog
TT10	0	TT20	Hedgehog	TT30	0
Total Registers	**7**	**Total Registers**	**3**	**Total Registers**	**5**

Figure 6-5: TT1 - Skink track

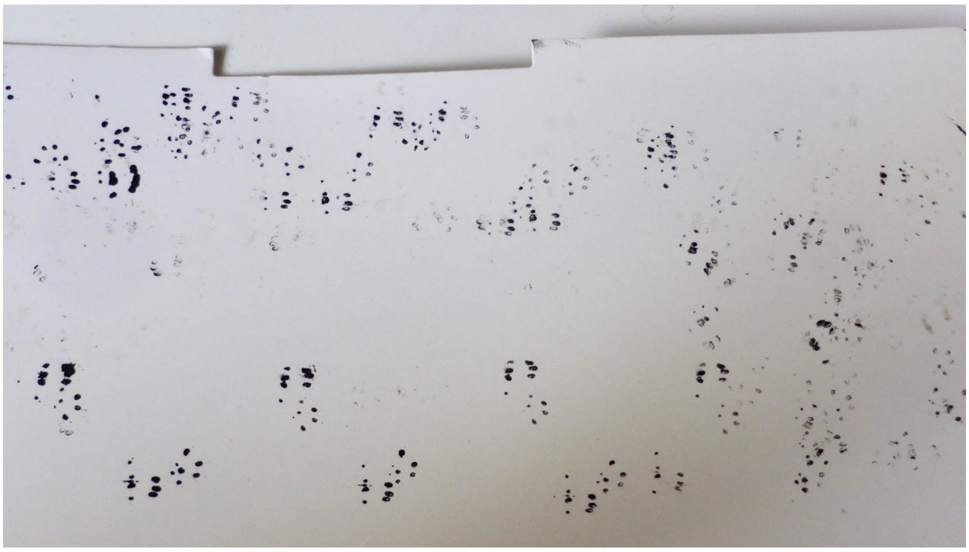

Figure 6-6: TT9 - Mouse track

Figure 6-7: ***TT26 - Hedgehog track***

6.4 Discussion

In the scope of Upper Rangitata and Rakaia Trapping Project DOC placed over 500 traps (among DOC150 double-sets, DOC250 single-sets, 42, Timms and #1.5 Victor leg-hold) around 3 sites in the Rakaia River, all of which consisted in a large area of bare shingle and gravel riverbed protected within a high-flow bend in the river (DOC, 2018-19). DOC's traplines were established on the adjoining river bank and trap's baits were fresh rabbit but in November and December, when Erayz^{TM} was used. The project ran from July to February. DOC registered cats, ferrets, stoats, weasels, possums, hedgehogs, rats, rabbits, hares, mice and exotic birds in the traps. Hedgehogs accounted for nearly 40% of captures. Similarly, this survey did registered hedgehogs as well. A higher number of them was observed in Line 3. It is possible that Line 1 environment is not as suitable for the species while Line 2 was settled in the same area as DOC's traps which might have already captured some. A dead hedgehog was observed near a DOC's trap in this area.

This survey placed a different bait than DOC's. Had it been possible to bait the traps also with meat, as initially intended, it is probable other species would have been registered, such as stoats. It is also important to consider that traps were settled just for about 24 hours. A longer period of sampling would provide more robust results. Furthermore, it is essential to acknowledge DOC has not launched this year's report hitherto, thereby the discussion is based on DOC last year report's results. Notwithstanding, we draw attention to the fact that the Trapping Project is limited in time and space, occurring only during a few months of the year and nearby the river. If resources allowed, running it throughout the year and broadening the area potentially would increase outcomes. Predator's populations are allowed to grow during the time the programme is off resulting in a higher risk for birds during nesting season. Even though Line 2 was placed near DOC's traps, hedgehogs were still tracked which could indicate DOC's traps are not 100% efficient. Nevertheless, it is not clear if DOC's traps were being checked at the time. In addition, DOC's traps were restrained to areas adjoining the river bank while we explored an area near the river as well as two other areas spanning away from the river. We have shown the presence of predators in those areas. Although DOC's choice to concentrate its resources nearest the birds' nests is understandable it might be worthy to consider the relevancy of widening the trapping area for the conservation of the threatened species.

6.5 Conclusions

The present survey was extremely concise compared to DOC's Trapping Project, however, it was still able to identify Wrybill and Black-fronted tern main predator in the area, the hedgehog. This fact endorses the big threat this species is for the endemic birds mentioned. We believe the expansion of DOC's project in the area as well as along the year would favour predator control and thus, the protection of the species. If support is needed, the Trapping Project could appeal to the Predator Free New Zealand plan, as the programme clearly contributes to this plan's major goal of eradicating predators.

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Chapter 7: **Hare populations at various altitudes**

Brittany Graham

7.1 Hare populations at Cleardale Station

Cleardale Station is located in the Rakaia Gorge and is an intensive foothill property of 1600 hectares. The property ranges from 300 to 700/800 m altitude, with the Department of Conservation owning the higher mountains above the farm. Cleardale Station is working with the Department of Conservation to trap pest predators such as stoats and cats around the river to protect the endemic wrybills and black-fronted terns that nest down by the riverbeds. The station uses different methods for controlling pest populations to ensure they are not affecting productivity of the farm or the native reserves and habitats. Pig and deer control occur only when there are large numbers on the property but, as of late, populations have been very low or absent. The station would use contracted hunters to control numbers. Rabbits were also a problem for many years but with the help of RHDV1 K5 which is a strain of rabbit haemorrhagic disease virus, the populations have been decreasing to numbers where currently they are not considered to be a massive pest problem. The property has all waterways fenced to keep the stock out and this enables re-establishment of the stream/rivers unique habitats and prevents livestock waste polluting the water and also ruining the banks of the streams as livestock moving around on them damages the banks and causes erosion which effects the invertebrates in these areas.

Brown hares (*Lepus europaeus*) were introduced to New Zealand between 1867 and 1871 as Australia were successfully importing them at the time. Brown hares are a fast-running terrestrial mammal with weight range between 3-4kg (Wong & Hickling, 1999). Females are larger than males but this is not particulalrly noticable in the field. Hares are often found in most pastoral and grassland areas of New Zealand as well as in alpine and subalpine areas. They typically begin feeding at dusk and may move some distance, often downhill to find grazing. They habitually use the same paths or 'runs' for movement downhill (Wong & Hickling, 1999). Hares may travel up to 15 kilometre while feeding in one night. Studies have shown hares to have a relative home range of 30 ha for females and 70 ha for males. During March to May, the non-breeding season, hares can extend their ranges from lower mountain slopes onto river terraces (Wong & Hickling, 1999).

Hare pellets (also known as faecal pellets or scats) are typically flattened spheres and are typically 15mm x 10mm in size with a slight 'tail' on one side. They are similar to rabbit pellets but are paler, larger and more fibrous in appearance. Hare pellets tend to be scattered widely whereas rabbit pellets are found in small piles.

Made the image lighter and added contrast

Figure 7-1: A comparison of hare and rabbit pellets.

Hares often eat the more nutritious bottoms of tussocks and other vegetation and leave the tops intact but the tips of plants are often left on the ground (Wong & Hickling, 1999). Hares can prevent regeneration of native plants in favoured hare habitats in the sub-alpine and alpine zones and can damage sensitive native vegetation around alpine ponds and wetlands. Hares also eat some plant species in restoration areas, especially during the first four to five months following planting (Wong & Hickling, 1999) which is an issue as there are a few restoration sites on Cleardale Station that are in the early stages of establishment. The objectives of the present study were:

1. To investigate the abundance of hare at various altitudes
2. To investigate the various habitats on Cleardale Station in regards to hare abundance

7.2 Methods

Plots that were 20m x 20m were set out at various altitudes from 760m to 310m as shown in Figure 1. Each plot was searched for hare scat and any other scat found in the area and noted down. Habitat type and landscape was also noted. A scale was made from 1-5 to show the amount of scat that was found and how close together the scat was to each other as shown in Table 2-1.

Table 7-1: Hare relative abundance levels based on scats

Hare abundance levels	**Scat densities (per** 10m^2)
1	Zero scat
2	1-3 scat piles
3	4-6 scat piles
4	7-10 scat piles
5	11-19 scat piles
6	20 or more scat piles

Figure 7-2: ***Sampling sites down an altitudinal transect (760m-310m)***

7.3 Results

As shown in Figure 2-3, hare abundance increased at lower altitudes, explaining most of the variance in hare abundance. Figure 2-4 shows the hare abundance indication by vegetation and highlights the gorse habitat has a higher abundance compared to the higher altitude habitats, although there is a presence of hares in all habitats at all altitudes.

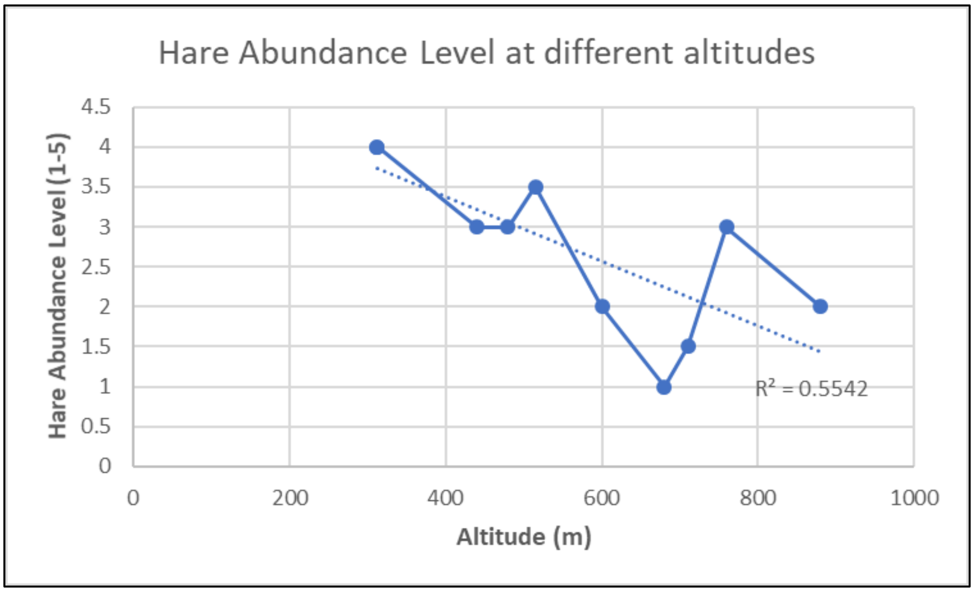

Figure 7-3: ***Hare abundance level at different altitudes***

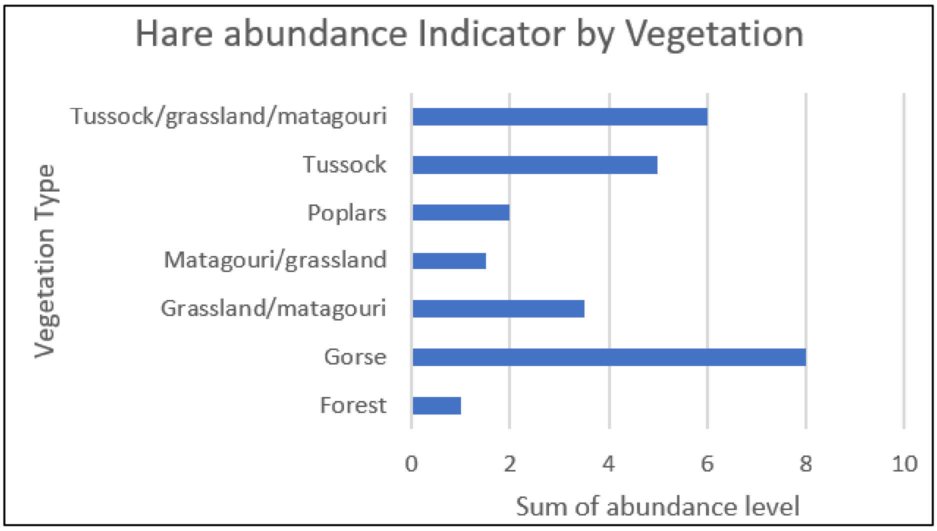

Figure 7-4: ***Hare abundance indicator by surrounding vegetation***

7.4 Discussion

Hare impact on vegetation in New Zealand has generally been considered an issue of relatively low conservation priority (Wong & Hickling, 1999), however it is imperative that control methods are put in place to decrease the impact of hares on native high altitude vegetation as well as vegetable crops for farm use and stock consumption. The average number of hares in Canterbury was estimated as 3 per kilometre (Flux, 1967). More recent studies of rabbits and hares have found combined numbers up to 50 per kilometre (Scroggie, Parkes, Norbury, Reddix, & Heyward, 2012). These authors predicted that in areas with less than 50 lagomorphs per kilometre, vegetation biomass would grow in all seasons apart from winter in degraded areas. More research will need to be done to accurately predict the number of lagomorphs per kilometre to then be able to know how effected vegetation biomass is overall on the station.

The higher altitude vegetation consisted of tussock, grasslands and a few shrubland areas. Until the European settlement, New Zealand's alpine grasslands were browsed only by flightless indigenous birds and invertebrates (Rose & Platt, 1987). But now almost no native grassland has escaped the effects of grazing by wild and feral animals (Wong & Hickling, 1999). Evidence that grazing can depress plant diversity is widespread (Wilson, 1994) and can affect the survival, growth and reproduction of plant communities (Wong & Hickling, 1999). As hares in this study were found predominantly at the lower altitudes, especially in the gorse/broom habitat, there would be potential consideration that if removing the gorse from the riverbed, would reduce habitat for hares and therefore reduce populations. Although removing hare habitat is possible, gorse and broom are one of the main plant species on the younger surfaces of Canterbury riverbeds and create habitats for native and exotic invertebrate species (Williams, 2012). They are also very fast spreading plants so first to eradicate the original population would be very labour intensive, also maintaining the spread would be rather expensive (Gould, 1976) (Williams, 2012) and may not be worth the stations time and money.

Hares may be susceptible to RHDV when dosed with very high levels of the virus (Parkes, Heyward, Henning, & Motha, 2004) so this virus or other viruses could be a potential control method for hares that is also proven to eradicate rabbits as well. As mentioned previously, the station had a wave of RHDV1 K5 that predominantly reduced the rabbit population considerably as there was a high number of rabbits causing an extent of damage to the property. Since then, it is suggested that as rabbits and hares are competitors of resources, the hare population may have increased as there would not have been any competition for resources (Katona, Biro, Hahn, Kertesz, & Altbacker, 2004). Therefore, if the hare population decreased and the RHDV1 K5 virus was bred out (due to resistance or other environmental reasons) then rabbit populations could potentially rebound.

7.5 Conclusion and recommendations

There were more hares at lower altitudes, especially in the gorse habitat by the riverbed, although there was an indication of hare abundance at all altitudes and different habitats including poplar, grassland and matagouri dominated sites. There was a high relative abundance of hares at the lower altitude gorse habitat. Improved control may be needed in future if hare populations are uncontrolled; prevention of population spikes may be the best option in the long run.

Recommendations are:

- To carry out more detailed research on hare population densities.
- To consider control of hares.
- For contracted hunters should to focus on the gorse habitat.

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Chapter 8: **Taniwha Restoration Strategy**

Lyra Chu

Abstract

Restoration plays a significant role especially in areas with high agricultural activity because it can contribute in making the farm sustainable. Restoring ecosystem functions like improving soil quality, nutrient cycling, pollination, biological control of insect pests and erosion control, to name a few, will not only contribute in improving the physical environment of the area, but will also help in increasing farm productivity over the years.

The Taniwha Restoration Area is very unique in terms of terrain or landscape and plant composition. The presence of a nearby forest patch (i.e. trail by the river), is already a contributing factor to increase the native vegetation in the area. However, invasive weeds like Gorse (*Ulex europaeus*) and Scotch broom (*Cytisus scoparius*) began emerging in the area due to the clear-cutting of Pine (*Pinus spp.*) and Sycamore (*Acer pseudoplatanus*) trees as shown in the photograph below.

Although through natural succession, native plants will eventually come back in the area but leaving it as it is will take a long time to happen. In addition, without proper management, more invasive species could dominate in the area which makes it harder for the native species to return.

There are various restoration strategies and land management practices to gradually eradicate problematic plants and increase native vegetation in the area, but since there is no "one size fits all" method for restoration, we have to first look at what is currently in the area through conducting a rapid site assessment. Gathering baseline data from the area to be restored before conducting any land management practices is important because the result can be used to identify which appropriate actions should be done. This data can also be used to track improvements in the site or determine if any specific activities (e.g. increase planting density, weeding in every 3 months, among others) were able to make a difference in terms of achieving the goal of the restoration site.

8.1 Findings during the rapid site assessment

During the assessment, the following were observed in the restoration site:

A. The site has a unique landscape wherein the area to be restored has a sloping terrain leading towards the grazing area. There are many implications for this type of site. The lack of vegetative cover makes the area susceptible for soil erosion. Although there are areas with tree cover, it is still not enough to effectively hold down the soil as seen in the photograph below.

Since there is a grazing area situated below or in a lower elevation than the restoration site, controlling soil erosion plays a vital role here because without a preventive mechanism in place, the steep slope can cause the soil to erode to the grazing area which can change its current soil nutrients and make it less productive.

B. Although problematic plants like Pine and Sycamore dominate the area, some native plants like Cabbage tree (*Cordyline australis*), Kohuhu (*Pittosporum tenuifolium*), Patē (*Schefflera digitata*), among others, were found growing in the understory. This tells us that the problematic trees served as nurse trees for native plants. However, without the proper management of Pine and Sycamore seeds and seedlings and the presence of pollinators within or passing by the area which contributes in dispersing invasive plants, this can impede the regeneration of native plants coming back to the site.

C. Invasive weeds such as Gorse and Scotch broom were seen to grow in open or barren areas and areas near the road where there is a huge amount of sunlight. The growth of these problematic weeds in fully shaded areas such as the understory of the Sycamore and Pine trees were limited.

D. Conservation practices like hand weeding and spraying have been conducted in the nearby forest patch. Although it is very effective in limiting the growth of invasive plants, it is highly laborious. The active engagement of volunteers from the community who help conduct these management practices are important not only in the conservation of native species through site maintenance, but this can also contribute to other social factors like strengthening the cultural integrity and environmental awareness of people in the community.

E. The location of the restoration site which is situated nearby farmlands in Rakia Gorge makes it an ideal conservation site not just for native biodiversity, but also to secure and maintain the delivery of ecosystem functions and services like water regulation and filtration, increase carbon storage and other benefits that are useful for a farming system.

F. In another site of the farm, which is located outside the restoration area, poison was used to kill the problematic trees instead of clear-cutting. As shown in the photograph below, native regeneration was also found in the understory of the trees.

Site where problem trees were poisoned

Understory vegetation of the site

Due to limited time, the observation of this area was not as detailed as the restoration site, but this was able to show that the method makes it possible for problematic trees to be slowly eradicated from the area but still providing shelter for the native plants. When it eventually dies, the trunk can serve as a habitat to lizards and other insects. The damage of fallen trees through this method is also less than clear-cutting the trees.

8.2 Conclusion and Recommendations

We observed that poisoning Pine and Sycamore had a notable impact in terms of bringing back native vegetation in the area. We could infer that this methodology in eradicating problematic trees is better than clear-cutting because it causes less damage when trees fall, can serve as shade trees for native regenerants, and the rotten trunk could serve as a habitat for invertebrates. Another method is to ringbark larger exotic trees wich removes the toxin from the environment and allows more natural breakdown by decomposers (fungi and invertebrates). Regardless, there is a need to conduct site maintenance to make sure that the native regenerants are not out-competed with invasive plants. This can be done by regular monitoring to weed-out invasive seedlings growing in the area. We realize that this is a laborious task but with a strong volunteering community, as well as the opportunity for Rakaia Gorge tourist to engage in such activities while they are hiking or trekking (i.e. identifying invasive weeds on the trail and help in hand weeding), this can be a great site maintenance strategy. There are also other natural approaches like increasing the tree cover of the area so that we can limit the invasive plants that tend to grow when the area has access to direct sunlight.

In increasing the tree cover of the area, the nearby forest patch can serve as a seed source. Other activities like planting native fruit bearing plants that pollinators are attracted to so that they can be diverted from dispursing blackberries and other weeds in the site is also another activity that can be done in the area . Planting fast growing plants to close the canopy quickly so that weed growth could be limited is also ideal. Furthermore, we could help nature fast-track natural succession by conducting enrichment planting where we plant native climax species which takes a long time to grow but at least this speeds up the process of native trees dominating the area. Increasing the vegetative cover and choosing plant species like *Dodonea viscosa*, *Fuchsia excorticata* and *Aristotelia serrata* that are deep rooted is also essential in holding down the soil to help prevent erosion.

Before doing restoration, it is also important to have an adequate data (e.g. soil profile, threats and disturbances aside from invasive plants and plant diversity) of the site so that we can trace if certain practices or strategies were effective or not. This means that a more detailed site assessment should be done for the baseline data and help us narrow down the interventions we need to do. In line with this, it is also important to set a clear objective or goal of the restoration project to help in identifying what needs to be done or give the project a sense of direction. This could be a general goal like “ to enhance native diversity for the conservation of regional flora and fauna”. Alternatively your aims may be “to restore healthy forest cover for climate change mitigation and securing the delivery of ecosystem goods and services to make the farm system more sustainable”. It can also be specific in terms of the number of native plants and wildlife found in the area over a certain number of years and other data-related objectives (e.g. increase native plant diversity by at least 70%) . Knowing how we envision the restoration site and deciding what the goal would be, is the first step in the process of developing a restoration plan. This is then followed by conducting a more detailed survey or assessment in the restoration site before beginning to do enrichment plantings and other maintenance and protection activities mentioned in the previous paragraphs.

Chapter 9: **Inventory of invertebrates, lizards, birds and some plant species known in Cleardale/Rakaia Gorge region**

Mike Bowie

Common name	**Species name**	**Link**	**Description/habitat/notes**
INVERTEBRATES: **N**= native; **I**= introduced; **U**=unknown			
Common grass moth[N]	*Orocrambus flexulosellus*	https://inaturalist.nz/observations/40505285	Common in grassy habitats
Soft wing flower beetle[N]	*Dasytes* sp.	https://inaturalist.nz/observations/40501432	Found in *Calystegia tuguriorum* flower. Pollinator
Native sweat bee[N]	*Lasioglossum* sp. (*L. sordidum*?)	https://inaturalist.nz/observations/36807108	Found in *Calystegia tuguriorum* flower. Good pollinators of smaller native species
Native plasterer bee[N]	*Leioproctus* sp. (*L. fulvescens*?)	https://inaturalist.nz/observations/40798907	Caught in yellow pan trap/pollinator
Carabid beetle[U]	*Demetridia* sp.	https://inaturalist.nz/observations/40505322	Found in shingle riverbed/predator
Soldier fly species[N]	*Odontomyia* sp.	https://inaturalist.nz/observations/40798903	Caught in yellow pan trap/pollinator
Buff-tailed bumble bee[I]	*Bombus terrestris*	https://inaturalist.nz/observations/40798892	Caught in yellow pan trap/pollinator
Dark sword-grass moth[I]	*Agrotis ipsilon*	https://inaturalist.nz/observations/40798890	Caught in yellow pan trap/pollinator
Clematis triangle moth[N]	*Deana hybreasalis*	https://inaturalist.nz/observations/40795473	Caught in blue UV light trap
Moth	*Austrocideria* sp. (*A. gobiata*?)	https://inaturalist.nz/observations/40795471	Caught in blue UV light trap
Large darkling beetle[N]	*Mimopeus opaculus*	https://inaturalist.nz/observations/40505241	Found under dead wood
Copper butterflies[N]	*Lycaena* sp.	https://inaturalist.nz/observations/40493381	Great pollinator; larvae feed on *Muehlenbeckia*
Dung beetle[I]	*Aphodius granarius*	https://inaturalist.nz/observations/40493428	Soil mixer
Common drone fly[I]	*Eristalis tenax*	https://inaturalist.nz/observations/40497970	Great pollinator and larvae feed on muck
Large hover fly[N]	*Melangyna novaezelandiae*	https://inaturalist.nz/observations/40498005	Great pollinator and larvae are aphid predators
Alexander beetle[N]	*Megadromus antarcticus*	https://inaturalist.nz/observations/40505314	Generalist predator
Water spider[N]	*Dolomedes aquaticus*	https://inaturalist.nz/observations/40505294	Generalist aquatic predator
Ground cricket[U]	*Bobilla* sp.	https://inaturalist.nz/observations/40505283	Herbivore & prey for lizards
NZ grasshopper[N]	*Phaulacridium marginale*	https://inaturalist.nz/observations/40505282	Herbivore
True bug[N?]	*Aradus* sp.	https://inaturalist.nz/observations/40505245	Associated with dead wood?

Cerambycid[N]	*Liogramma zelandicum*	https://inaturalist.nz/observations/40501472	Hosts include kowhai, Manuka, Pittosporum,etc
Lichen darkling beetle[N]	*Artystoma* sp.	https://inaturalist.nz/observations/40501466	Feeds on lichen on rocks and trees
Ground beetle[N]	*Mecodema (Metaglymma)* sp.	https://inaturalist.nz/observations/40501460	Predator
Red-winged lycid[I]	*Porrostoma rufipennis*	https://inaturalist.nz/observations/40501442	Found in rotting wood
Plantain moth[N]	*Scopula rubraria*	https://inaturalist.nz/observations/40501434	Larvae feed on *Plantago lanceolata*
Land planarians[U]	Geoplanidae	https://inaturalist.nz/observations/40501430	Predator of earthworms
Smooth hard-bodied harvestman[N]	*Nuncia* sp.	https://inaturalist.nz/observations/40501427	Predator of small invertebrates
Flatworm[N]	*Arthurdendyus*	https://inaturalist.nz/observations/40501425	Predator of earthworms
Flatworm[N]	*Arthioposthia subquadranqulata*	https://inaturalist.nz/observations/40501405	Predator of earthworms
Leaf-vein slug[N]	*Pseudaneitea* sp.	https://inaturalist.nz/observations/40501416	Feed on fungi; can clear sooty mould off leaves
Ground beetle[N]	Agonum sp.	https://inaturalist.nz/observations/40498006	Predator
moth[N]	*Asaphodes* sp.	https://inaturalist.nz/observations/40795468	Adults pollinators?; larvae herbivores
Birds nest moth[I]	*Monopis crocicapitella*	https://inaturalist.nz/observations/40795461	Adults pollinators?; larvae herbivores
Noctuid moth[N]	*Ichneutica propria*	https://inaturalist.nz/observations/40795459	Adults pollinators?; larvae herbivores
Forest shield bug[N]	*Oncacontias vittatus*	https://inaturalist.nz/observations/40795463	Larvae are herbivores
Geometrid moth[N]	*Xanthorhoe semifissata*	https://inaturalist.nz/observations/40795456	Adults pollinators?; larvae herbivores
Grass moth[N]	*Orocrambus ramosellus*	https://inaturalist.nz/observations/40795450	Larvae are herbivores
Caddisfly[N]	Trichoptera	https://inaturalist.nz/observations/40795446	Food for fish, invertebrates and birds
Wide-banded tiger beetle[N]	*Neocicindela lateecinta*	https://inaturalist.nz/observations/40793569	Predator. Nests in open banks or cliffs
Moth[N]	*Paranotoreas brephosata*	https://inaturalist.nz/observations/40793567	Adults pollinators?; larvae herbivores
Kowhai moth?	*Uresiphita* sp.	https://inaturalist.nz/observations/40793566	Could be kowhai moth or similar species
Carpet moth [N]	*Helastia corcularia*	https://inaturalist.nz/observations/40793564	Light trap. Native forest to subalpine vegetation
Dusky scuttler[I]	*Opongona omoscopa*	https://inaturalist.nz/observations/40742677	Adults pollinators?; larvae herbivores
Cranefly[N]	*Chlorotipula* sp.	https://inaturalist.nz/observations/40742675	Larvae break down organic matter e.g. rotten logs
Chafer beetle[N]	*Odontria* sp.	https://inaturalist.nz/observations/40742669	Herbivore
True bug		https://inaturalist.nz/observations/40742668	
Diamondback moth[I]	*Plutella xylostella*	https://inaturalist.nz/observations/40742673	Pest
Wolf spider[N]	Lycosidae	https://inaturalist.nz/observations/40742664	Generalist predator
Giant earthworms[N]	Megascolecidae	https://inaturalist.nz/observations/40508733	Usually found in undisturbed soils with natives

Cosmopolitan ground beetle[I]	*Laemostenus complanatus*	https://inaturalist.nz/observations/40507446	Most common exotic carabid
Leafcurling sac spiders[U]	*Clubonia* sp.	https://inaturalist.nz/observations/40742660	Generalist predator
Shore bugs[N]	Saldidae	https://inaturalist.nz/observations/40507469	Semi aquatic species
Flatworm[N]	*Arthurdendyus testaceus*	https://inaturalist.nz/observations/40508734	Under logs and rocks; earthworm predator
Fly[I]	*Anthomyia punctipennis*	https://inaturalist.nz/observations/40742652	Pollinator?
Huhu[N]	*Prionoplus reticularis*	https://inaturalist.nz/observations/40507448	Larvae live in dead trees
NZ blue blowfly[N]	*Calliphora quadrimaculata*	https://inaturalist.nz/observations/40508721	Important pollinator of crops and alpine plants
Nurseryweb spider[N]	*Dolomedes minor*	https://inaturalist.nz/observations/40507462	Predator
Chafer[N]	Scarabaeidae	https://inaturalist.nz/observations/40507495	Herbivore
Ant[U]	Myrmicine	https://inaturalist.nz/observations/40507504	Some ants disperse seeds
11-spotted ladybird[I]	*Coccinella undecimpunctata*	https://inaturalist.nz/observations/40507482	Predator of aphids, scales, mealybugs
Magpie moth (larva)[N]	*Nyctemera annulata*	https://inaturalist.nz/observations/40507478	Feed on *Senecio* sp.
Meadow spittlebug[N]	*Philaenus spumarius*	https://inaturalist.nz/observations/40507481	Sucking herbivore
Snake millipedes[N]	Julidae	https://inaturalist.nz/observations/40742654	Breakdown organic matter
Ground beetle[N]	*Actenonyx bembidioides*	https://inaturalist.nz/observations/40505244	Predator
Canty alpine boulder copper[N]	*Lycaena tama*	https://inaturalist.nz/observations/40629050	Pollinator. Larval host is *Muehlenbeckia axillaris*
Spur throated grasshopper[N]	*Sigaus villosus*	https://inaturalist.nz/observations/36927845	2000masl bare scree
Mountain stone weta[N]	*Hemideina maori*	https://inaturalist.nz/observations/34344150	In scree, sub-alpine. Can survive freezing
Scree weta[N]	*Deinacrida connectens*	https://inaturalist.nz/observations/36927847	Subalpine, under rocks
Moth[N]	*Asophodes abrogata*	https://inaturalist.nz/observations/28205749	Subalpine?
Land planarian[N]	*Newzealandia* sp.	https://inaturalist.nz/observations/40508729	Predator of earthworms
LIZARDS (all endemic)			
Southern Alps gecko	Hoplodactylus "southern alps"	https://inaturalist.nz/observations/40505264	Under rocks in stream bed
McCann's skink	*Oligosoma maccanni*	https://inaturalist.nz/observations/40505313	Under log washed down river
Spotted skink	*Oligosoma lineoollatum*	https://inaturalist.nz/observations/38113198	Nationally vulnerable
BIRDS (all native)			
Black-backed gull		https://inaturalist.nz/observations/18752682	Dead by nest on riverbed
Banded dotterel		https://inaturalist.nz/observations/18752646	Nesting & dead bird on riverbed
Kea		https://inaturalist.nz/observations/4258346	Higher altitude/ Sub-Alpine
Paradise Shelduck		Recorded by Fraser Gurney on Cleardale	

Grey Teal		Recorded by Fraser Gurney on Cleardale	
Australasian Shoveler		Recorded by Fraser Gurney on Cleardale	
Black Shag		Recorded by Fraser Gurney on Cleardale	
Eurasian Coot		Recorded by Fraser Gurney on Cleardale	
Spur-winged Plover		Recorded by Fraser Gurney on Cleardale	
Australasian Harrier		Recorded by Fraser Gurney on Cleardale	Carrion, mice, rabbits, birds
Sacred Kingfisher		Recorded by Fraser Gurney on Cleardale	Carnivore – inverts, lizards, fish
Grey Warbler		Recorded by Fraser Gurney on Cleardale	Insectivore - larvae
New Zealand Bellbird		Recorded by Fraser Gurney on Cleardale	Nectar feeder, insects, berries
New Zealand Fantail		Recorded by Fraser Gurney on Cleardale	Insectivore – moths, etc
Silvereye		Recorded by Fraser Gurney on Cleardale	Frugivores
Welcome Swallow		Recorded by Fraser Gurney on Cleardale	Usually around water
Australasian Pipit		Recorded by Fraser Gurney on Cleardale	Open areas, tussock
Plants			
Speargrass; spaniard	*Aciphylla subflabellata*	https://inaturalist.nz/observations/2446712	*Aciphylla* seen on true right of Hydro stream
	Montia erthrophylla	https://inaturalist.nz/observations/20445047	Higher altitude scree
Necklace fern	*Asplenium flabellifolium*	https://inaturalist.nz/observations/40508757	
Dwarf club mistletoe	*Korthalsella clavata*	https://inaturalist.nz/observations/5056470	
Mountain lacebark	*Hoheria lyallii*	https://inaturalist.nz/observations/40507515	
Fuchsia	*Fuchsia perscandens*	https://inaturalist.nz/observations/40507514	
Needle-leaved mountain cop.	*Coprosma rugosa*	https://inaturalist.nz/observations/40508724	
Tutu	*Coriaria sarmentosa*	https://inaturalist.nz/observations/40508725